MP ENSYSTEMS

GREENING RURAL VALUE CHAINS IN MADHYA PRADESH

JANUARY
2023

MP ENSYSTEMS

Acknowledgements

We would like to thank all the individuals and institutions representing policy makers, academia, public and private sector for meeting with us, participating in workshops and providing data and insights on the rural value chain. This document reflects the views of the authors and not that of any other parties.

About MP Ensystems

MP Ensystems Advisory Pvt. Ltd. is a research-driven private consulting firm set up in 2012 actively supporting equitable energy and resource efficiency measures. The MP Ensystems team for this project comprised: Dr Mahesh Patankar, Meenal Sutaria, Ira Athale Prem, Prajkta Adhikari, Asmita Ekawade, Hrishabh Chandra, Kaustubh Alekar, Smitha Lobo and Rutal Deshmukh (intern).

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MP ENSYSTEMS

About this document

MP Ensystems has worked since 2022 in selected districts of Madhya Pradesh, with the aim of promoting low carbon high growth in rural areas, through greening agricultural and horticultural value chains. The project outputs include standardised packages of horticulture farm-to-fork practices through energy efficiency (EE) and renewable energy (RE) interventions and a proposed policy on decentralised RE in rural value chains, which are described in this report. The team has also identified skills gaps and facilitated training and entrepreneurship opportunities in agrivoltaics through e-learning modules in English and Hindi.

English (part 1: https://www.youtube.com/watch?v=Au99GiT-lYw)

English (part 2: https://www.youtube.com/watch?v=sW8PxHm5yLM)

Hindi (part 1: https://www.youtube.com/watch?v=d5GC7v7QdUU)

Hindi (part 2: https://www.youtube.com/watch?v=MhMAYOSfVpI)

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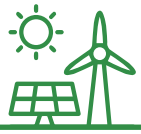


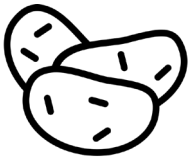
EXECUTIVE SUMMARY

The aim of this project is to promote green rural value chains in Madhya Pradesh, by developing standardised packages of horticulture farm-to-fork practices targeting RE interventions, proposing a policy on decentralised RE in rural value chains and developing training modules in partnership with educational institutes.

Under the MP Government's One District One Product (ODOP) scheme, potato growing is promoted in Chhindwara, turmeric in Shahdol and mango in Umaria, Siddhi and Singrauli. Site visits to the districts of Chhindwara, Shahdol and Umaria provided the following information related to prevalence of farming, post-harvest processing infrastructure and market linkages:

POTATO	TURMERIC	MANGO
• Contract farming implemented with FMCG companies, hence production on commercial scale	• Farmers lack forward market linkages and hence production is not at commerical scale	• Locals own orchards for decades, but miss out on commercial scale market
• Cold storage facility available locally	• Absence of cold storage facility	• Absence of cold storage facility opportunities
• Absence of processing units at district level	• Processing plants at nascent stage, most grind turmeric at home	• Inspite of being declared under the ODOP scheme, district lacks processing units

Based on meetings with farmers, agriculture scientists, technology providers, academic institutions, and analysis of suitable technologies, the team proposed the following classification of EE and RE interventions for established, emerging and nascent agricultural produce.



POTATO

- Well established value chain
- Contract farming by MNCs
- Other crops to be focused are Maize, Oranges, Tomatoes

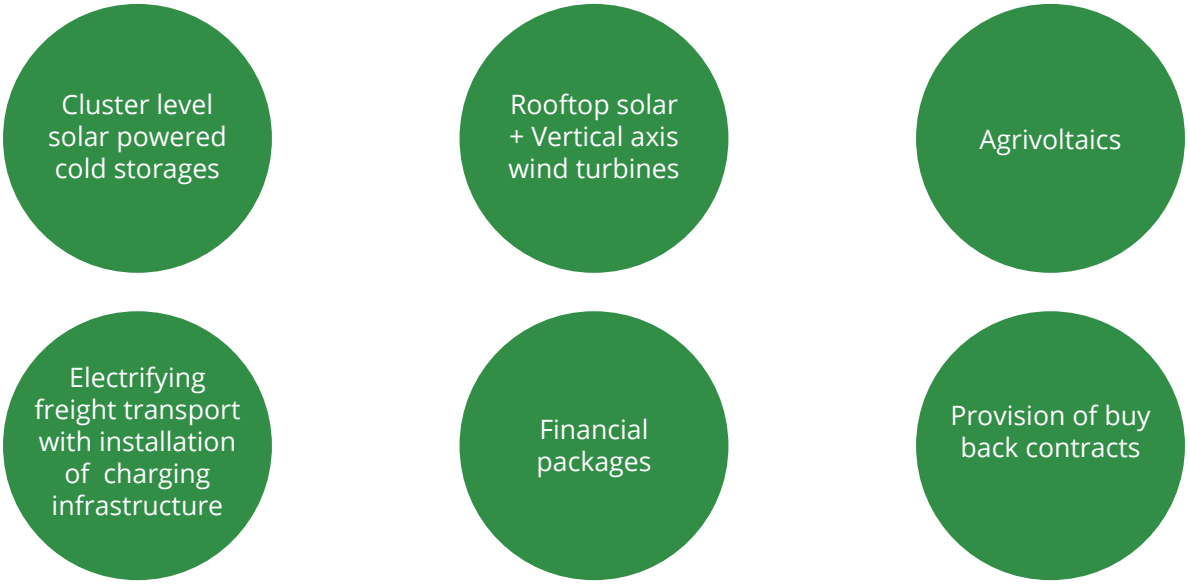
TURMERIC

- FPOs plan to set up integrated plant for processing and packaging
- Forward market linkages missing
- Govt. sponsored subsidy scheme

MEDICINAL PLANTS

- Huge potential for commercial use farming as favorable weather
- and soil conditions
- Huge demand with renewed impetus an organic and

PROPOSED INTERVENTIONS



These interventions, if scaled up, are expected to yield the following benefits:

Technological interventions and their benefits:

Intervention	Beneficiaries	Technical Potential	Economic Potential	Market Potential	Cost INR crore	GHG Reduction, tCO2	Simple payback on investment years
Rooftop Solar PV for large cold storage plant	302 cold stor-ages with total capacity of 12,93,574 MT	40.77 MW	8.15 MW	0.82 MW	5.3	22,082.7	9.6
Rooftop PV for small Haldi Processing plant	300 haldi pro-cessing plant with 3 kW of rooftop PV	0.9 MW	0.18 MW	0.02 MW	0.1	3,557.9	7.4
Solar dryer	14,98,750 agri households	59,95,000 units	11,99,000 units	1,19,900 units	407.7		0.3
RE based Dis-tributed Cold storage	At 259 mandis	25.90 MW	5.18 MW	0.52 MW	12.5	5,801.6	3.1
Agrovoltaics	1,40,95,000 ha of degraded land and wastelands	5,015.5 MW	1,003.1 MW	100.3 MW	501.5	25,75,990.1	8.4
Low-cost cool-ing option	14,98,750 agri households	14,98,750 units	2,99,750 units	29,975 units	83.9		0.6
Freight EVs	5,99,500 agri households	5,99,500 units	1,19,900 units	11,990 units	438.8	1,91,840.0	4.7

Source: MP Ensystems Research 2022

In order to promote better RE solutions and greening of value-chains, we propose a policy intervention to promote Decentralized RE in Rural Value Chains. These policy interventions will lead to the following goals:

- **Promote green rural value chains that have net zero emissions, are climate resilient and climate adaptive**
- **Create green rural employment opportunities in agriculture, manufacturing and services**
- **Enhance livelihood and employability through upskilling and reskilling of the workforce in partnership with educational institutions in the state**

The policy would provide financial incentives to farmers and supply chain partners for RE and EE technologies in the form of standardised packages containing the following interventions, from which beneficiaries can select the appropriate suite of interventions; also providing implementation pathways. The agency managing the implementation would also conduct training programs in partnership with educational institutions and industry and undertake awareness campaigns, as well as disseminating information on technologies and service providers. Annual evaluation of the programs benefits vs its costs will provide guidance on modifying targets, benefits and technologies for the next year. A summary of the policy proposal is below:

POLICY PROPOSAL: DECENTRALIZED RE IN RURAL VALUE CHAINS

The state's roadmap to 2023 under Atmanirbhar MP covers physical infrastructure (including energy), governance, health and education (including training), economy and employment (including agriculture market reform). A policy or programmatic intervention in the rural value chain can become a part of the Atmarnirbhar MP process, under physical infrastructure. This is expected to fill a gap in the plan, help the state achieve its decarbonisation targets, while promoting enhanced income and livelihood in rural areas, where over 70% of its population resides. The details are below.

Vision

- **Create farm-to-fork leadership in the country by linking rural areas with urban centers**
- **Promote green rural value chains that have net zero emissions, are climate resilient and climate adaptive**
- **Create green rural employment opportunities in agriculture, manufacturing and services**
- **Enhance livelihood and employability through upskilling and reskilling of the workforce in partnership with educational institutions in the state**

Targets for phase I

- **Enhanced livelihood opportunities in 20% of districts through horticulture value chains**
- **Participating rural enterprises to generate 50% of energy from renewables**
- **Create a mesh of charging network for EVs in freight transport to be set up along five major agriculture/ horticulture corridors in state**
- **Entrepreneurship and skill development programs to be conducted in 50% of the districts**

Proposed interventions and budget

The table below shows the proposed interventions, with government expenditure of 10% of technology cost (as incentive, rebate, subsidy or other mechanism), along with training and management costs for the first year. The source of funds is the MP state general budget.

Proposed interventions and expected government expenditure

Intervention	Govt Expenditure, INR Crore
Rooftop Solar PV for large cold storage plant	0.5
Solar dryer	40.8
RE based Distributed Cold storage	1.3
Agrovoltaics	50.2
Low-cost cooling option	8.4
Freight EVs	43.9
Training	30
Dissemination	10
Program Management	20

Source: MP Ensystems Research 2022

During the evaluation in year 2, the management team can estimate direct and indirect benefits of the program in terms of raising income, generating employment and reducing GHG emissions. Future benefits and targets can be set accordingly.

FARMERS

- Increased income from selling value added commodities
- Lowered energy cost
- Enhanced resilience to price variations, extreme weather shocks

NON-FARMING RURAL POPULATION

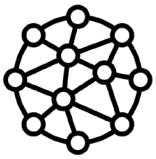
- Employment opportunities in food processing, RE and EE installation and maintenance

INDUSTRY

- Enhanced opportunities for trucking, logistics firms, retailers
- Opportunity in EV charging, maintenance

STATE POPULATION

- Improved connectivity between rural and urban areas
- Improved performance of state electricity utilities
- Improved air quality from reduced DG set use



TECHNOLOGY INTERVENTIONS

- Prepare a suite of RE and EE interventions
- Get feedback from farmers, industry and public to improve interventions

TRAINING AND SKILL DEVELOPMENT

- ITIs, IIT, Govt training institutes to offer training in relevant

FINANCIAL PACKAGES

- Partner with banks, FIs, industry to provide district-wise schemes

INFORMATION DISSEMINATION

- Provide information on benefits
- Create directory of technologies and service providers

The program is expected to be led by the Farmer Welfare and Agriculture Development Department. Since inputs are required from other Government departments and agencies, an empowered group can administer the program, with members from the following ministries and departments: rural development, electricity, food processing industries, MSME, and skill development, finance. The government can also seek inputs of premier educational institutes in the state, farming, and industry representatives.

Alternatively, the government can set up a company with the objective of just transition, i.e. aiming at greening the economy while promoting the interests of weaker sections of society. The Maharashtra Government has set up MAHAPREIT (Mahatma Phule Renewable Energy and Infrastructure Technology Limited), which is currently working in the areas including setting up EVCI, affordable housing and agro processing value chains in partnership with rural women's groups. Such an entity could spearhead the program.

Proposed interventions, responsibilities and expected outputs are in the table below.

Sectoral initiatives and their outcomes

Interventions	Outputs	Responsibility	Source of Funding
Listing technology interventions	Suite of EE, RE interventions suitable for MP agro climatic zones, solar insolation levels and local industries	MP Government to appoint consultant to study suitable EE and RE solutions	MP Government budget
Training and Skill Development	Training programs on EE, RE equipment installation and maintenance; EV charging and EV maintenance; entrepreneurship in green sectors;	Directorate of Skill Development to use existing infrastructure; In partnership with ITIs, IIT Indore for course development; private sector to provide inputs and participate in job placement	Existing MP Skill Development Mission funds; ITI and other institutes; Private sector sponsorship
Financial package	Loans targeting RE, EE, EVs in rural sector	District lead banks	Bank lending, with additional interest rate subventions from Government programs and donor agencies
Awareness and Dissemination	Government machinery to provide information on program in rural areas through radio, TV, newspaper ads Government to host website with service providers, technologies and financing information	Rural development ministry to inform panchayats of program Government to partner with industry to host website	Website to be part financed by industry
Monitoring and Evaluation	Studying the benefits, costs, effectiveness of the interventions Results to be used to modify future iterations of the programs	Nodal agency for the project	MP Government budget

Source: MP Ensystems Research, 2022

CONTENTS

1. INTRODUCTION

MP Ensystems worked on a project aimed at greening rural value chains in the following coal-rich districts of Madhya Pradesh: Chhindwara, Umaria, Shahdol, Singrauli and Siddhi. The approach followed by the MP Ensystems team is in the figure below.

VISIT STAKEHOLDERS
Government, scientists, farmers, technology service providers

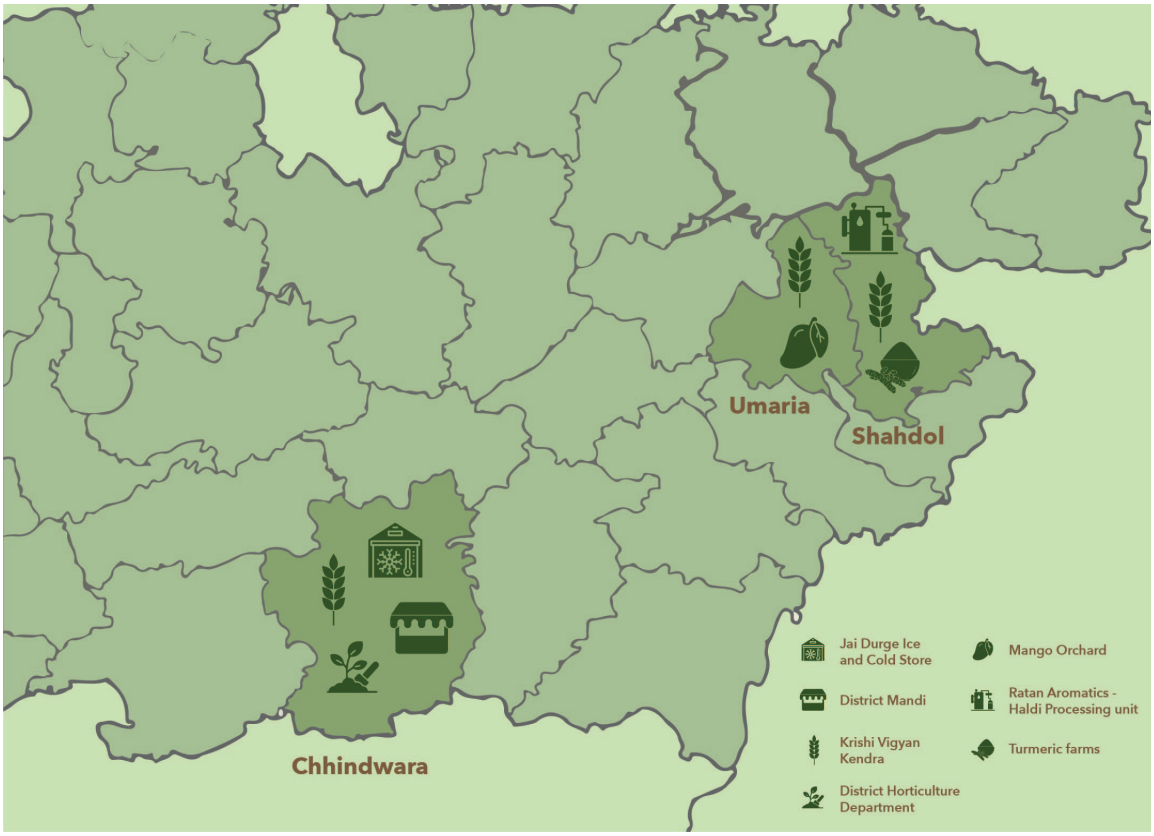
GATHER PRIMARY AND SECONDARY DATA
From site visits to villages, conduct surveys and interviews on agricultural value chain, inputs, costs, energy and water consumption, training, incomes and opportunities; Gather secondary data on socio-economic conditions, Govt schemes

EE AND RE INTERVENTIONS
Study suitable technologies -EE, RE, EV, low cost zero energy solutions

ESTIMATE IMPACT
Estimate costs, benefits of interventions to farmer, community and state

PROPOSE POLICY INTERVENTION
State level policy with packages, cost, administration, dissemination and evaluation

MP Ensystems visited agriculture and horticulture sites, processing facilities and supply chain partners in the selected districts.



Based on research conducted in the prior phase of the project as well as feedback from stakeholders, this report contains:

- **Packages of horticulture farm-to-fork practices targeting RE interventions**
- **Proposed policy on alternative livelihood opportunities programs for rural areas.**

This report is structured as follows:

Chapter 2 provides a short summary on the coal-rich areas of MP that are under study as a part of this project.

Chapter 3 describes the agricultural and horticultural products promoted in MP districts under the One District One Product scheme, some of which will form the basis for the RE interventions.

Chapter 4 provides an overview of RE and EE technologies and solutions that can be adopted in the selected districts, along with the expected benefits of cost saving, employment opportunities and decarbonisation. This chapter also contains a list of packages that can benefit small and large farmers as well as rural communities.

Chapter 5 describes public and private financing sources, as well as alternative financing instruments.

Chapter 6 describes current Government programs that aim at greening rural enterprises and a proposal for a policy intervention at the state level, that will help the state achieve its targets.

Chapter 7 contains a description of the role of stakeholders in promoting green value chains in MP.

Annexure I contains a description of the technology interventions and calculations on energy savings and financial impact.

2. PROJECT FOCUS AREA: COAL-RICH DISTRICTS OF MP

Some of the main central government schemes that finance post-harvest storage and processing are:

Madhya Pradesh has

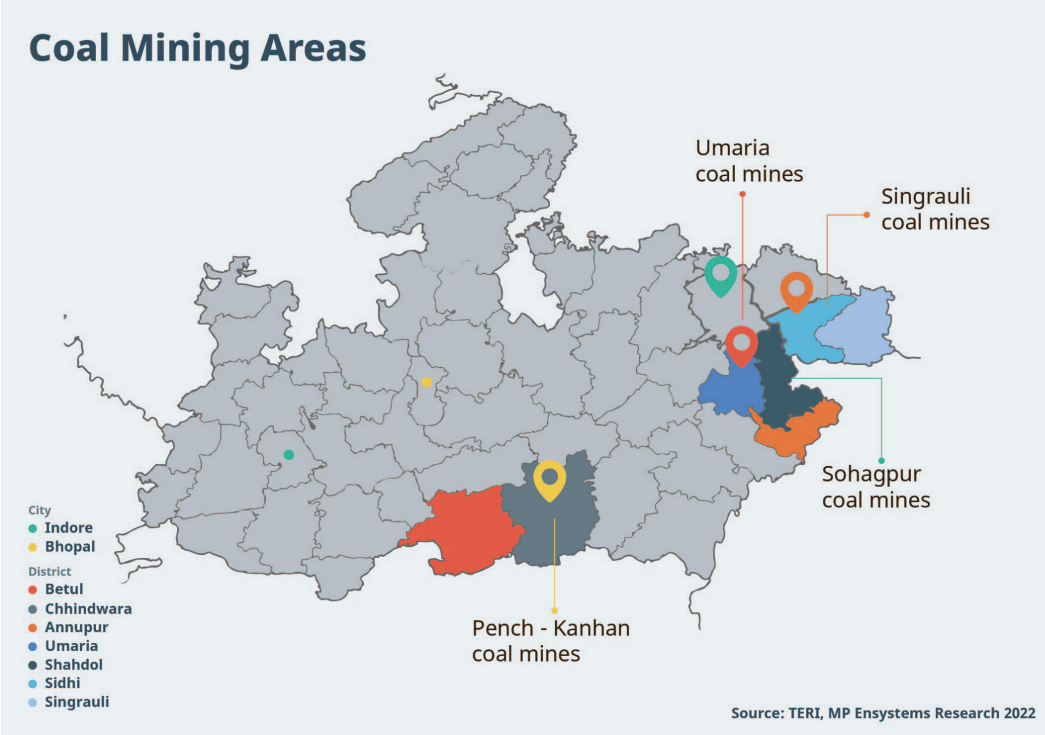
8%

of the total coal resources of India, and contributes to

13%

of Indian coal production.

The total number of coal mines in Madhya Pradesh in 2021 is estimated at 71, comprising 21 opencast mines, 48 underground mines, and 2 mixed mines . The major coal mining districts in MP, as highlighted in the map below, are in the south and east of the state, namely Chhindwara, Umaria, Shahdol, Singrauli and Siddhi. The coalfields are shared by other states like Maharashtra in the South and Chhattisgarh in the East.



- Locals are not employed as coal miners due to two reasons:

- **The work as daily wage labourers is highly labour intensive and quite underpaying, due to which there is a reluctance among the villagers to work in the mines, especially among the younger generation.**
- **Even informal work is not readily available throughout the year and becomes available during summers as there are not many workers willing to work in the mines due to the scorching heat, leading many to quit.**

- Locals are in informal employment including working as drivers or sometimes as daily wage labourers

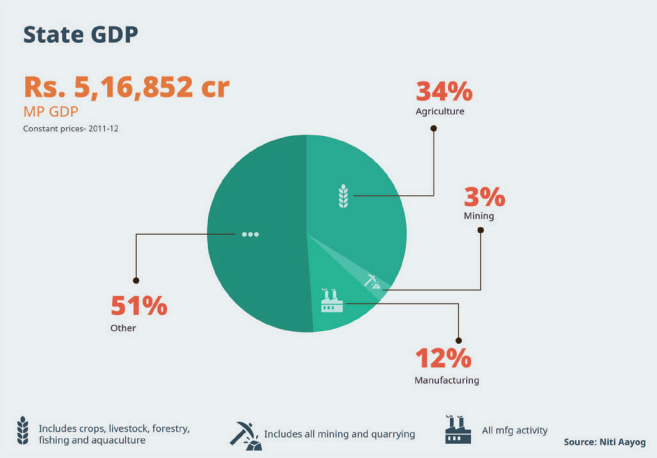
- Absence of employment opportunities for women in the mines

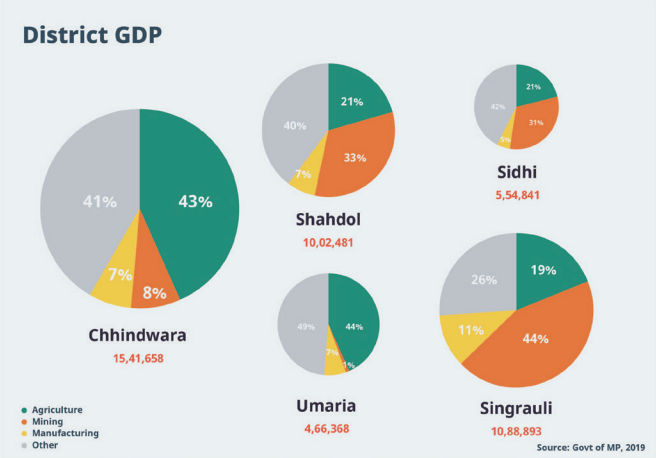
- Absence of income generating activities for nearby villages

- Most of the villagers are employed in agriculture of paddy crops, while those who are unable to find work here, migrate

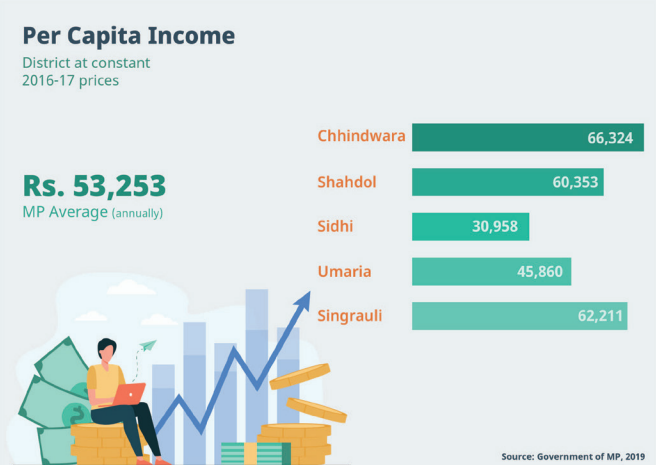
Source: Interview of residents of villages near Kanchana Coal Mine, Umaria

MP's state GDP stood at **INR 5,16,852 cr in 2021**, at 2011 prices. Agriculture, horticulture and allied activities accounted for 34% of the state's GDP. In the selected districts, agriculture accounted for close to 30% of Chhindwara's GDP, while mining contributed to more than half of Singrauli's GDP. The district GDP data is for 2016-17.





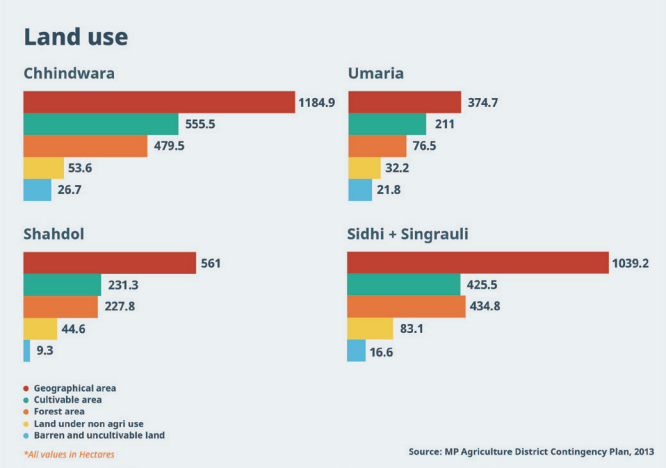
The district of Siddhi with a Per Capita Income (PCI) of INR 30,000 -compared to India's PCI of INR 82,269 - had half the per capita income of the other districts.

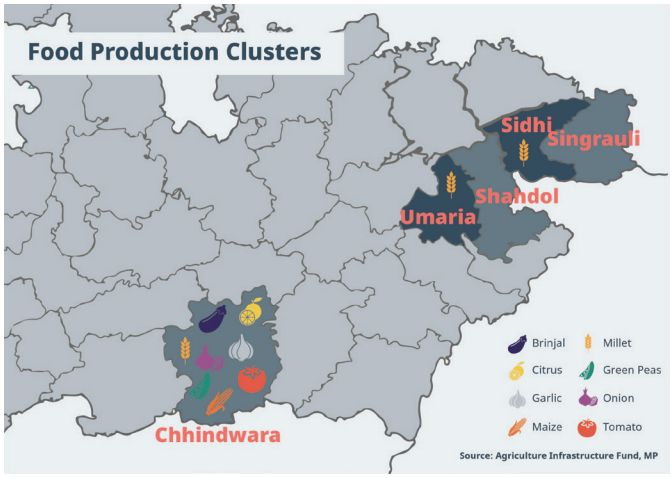


Agricultural sector

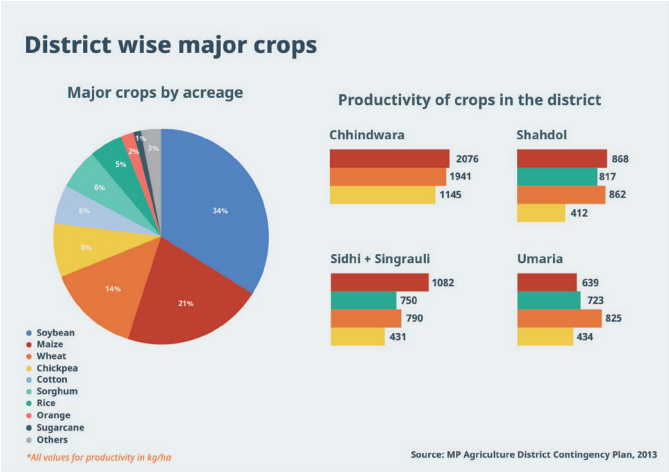
Madhya Pradesh is the second largest state in the country by area. Out of the total geographical area 307.56 lakh hectares of the state, only about 151.91 lakh hectares are arable. The total irrigated area in the State is about 110.97 lakh hectares . Agriculture and related occupations in Madhya Pradesh are the backbone of the state's economy.

Chhindwara and Umaria both have over 20% of barren land (according to the Agriculture Contingency Plan 2013) that can be availed for alternate uses such as RE generation, watershed management, industrial parks, agrovoltaics etc.



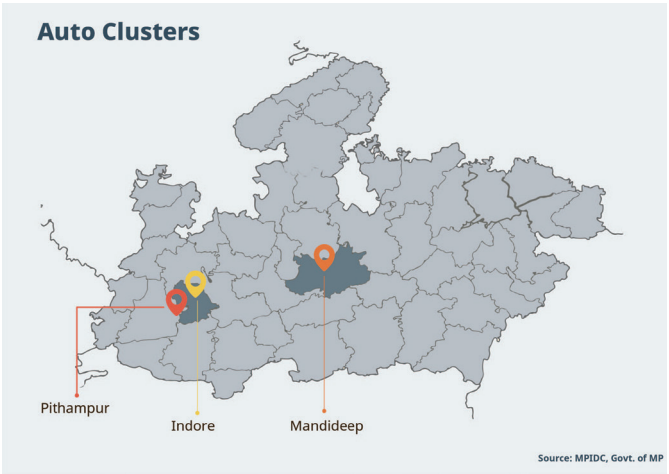


Chhindwara is known as the maize district and has agro clusters of cereals, fruit and vegetables. While Shahdol is among the top turmeric producing districts in the state, it does not have a turmeric production cluster in the district. Singrauli does not include any agricultural or horticulture clusters .



Automobile sector

In the automobile sector, Madhya Pradesh has over 30 OEMs (Original Equipment Manufacturers), over 100 engineering manufacturers, and over 200 auto component manufacturers. The major auto cluster in the state is at Pithampur, near Indore. The state also has the National Automotive Test Tracks (NATRAX) located near Pithampur. While there are only a small number of Electric Vehicle (EV) manufacturers, EV Charging Infrastructure (EVCI) manufacturers and Charge Point Operators (CPOs) in the state's auto cluster, with growing electrification of transport, there is potential for EVs and allied sectors to grow. Existing EV players include Gatti, EV Urja and E-Savari. The selected districts do not currently have auto industry clusters.



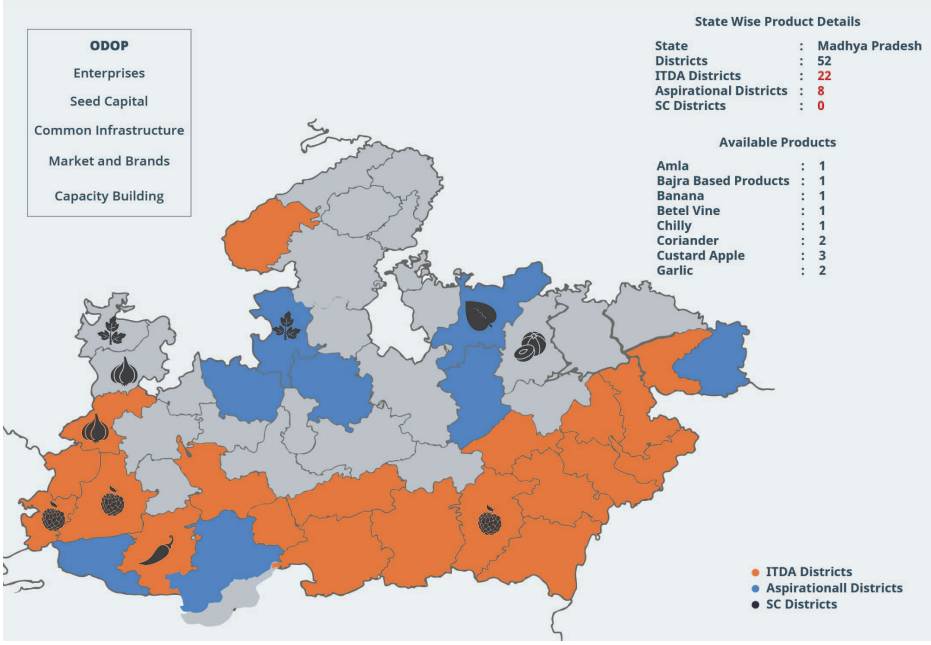
3. ODOP SCHEME AND PRODUCT VALUE CHAINS

This chapter covers the Central and State Government's promotion of One District One Product scheme, the value chains for potato, turmeric and mango, medicinal herbs and proposed interventions for the selected districts.

3.1 ODOP scheme

The 'One District, One Product' (ODOP) scheme was launched by the Ministry of Food Processing Industries under the Pradhan Mantri Formalisation of Micro Food Processing Enterprises Scheme (PMFMFPE) in 2021. The objective of the scheme is to help districts reach their full potential, foster economic and socio-cultural growth, and create employment opportunities, especially in rural areas. It aims to do this by identifying, promoting and branding one product from each district.

The ODOP scheme aims to turn every district in India, into an export hub through promotion of the product in which the district specialises. The initiative plans to accomplish this by scaling manufacturing, supporting local businesses, finding potential foreign customers and so on, thus helping to achieve the 'Atmanirbhar Bharat' vision.



Source: Ministry of Ministry of Food Processing Industries

The salient features of the ODOP scheme are below :

ODOP scheme

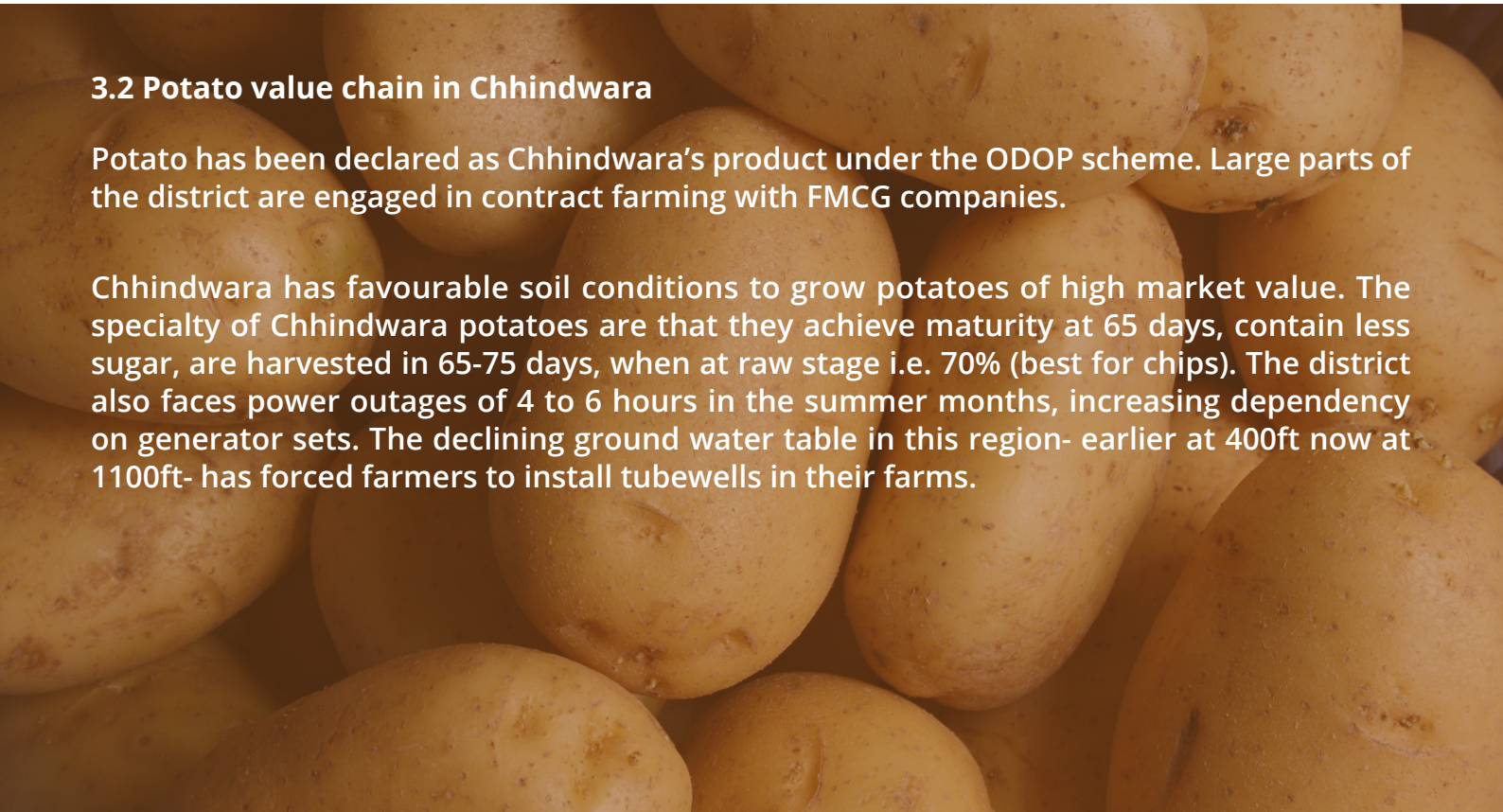
- Support for agricultural products for processing, along with efforts to reduce wastage, and storage and marketing.

- For providing support to existing individual micro-units for capital investment, preference would be given to those producing ODOP products. However, existing units producing other products would also be supported. In the case of capital investment by groups, predominately those involved in ODOP products would be supported.

- Support to groups processing other products in such districts would only be for those already processing those products and with adequate technical, financial, and entrepreneurial strength. New units, whether for individuals or groups would only be supported for ODOP products.

- Support for common infrastructure and marketing and branding would only be for ODOP products. In case of support for marketing & branding at the State or regional level, the same products of districts not having that product as ODOP could also be included.

The products under the ODOP scheme are potato for Chhindwara, turmeric for Shahdol and mango for Umaria, Siddhi and Singrauli. The team explored cultivation under the ODOP scheme for the selected five districts, through visits to Chhindwara, Shahdol, Umaria and Siddhi, conducting in person and phone interviews with farmers, farmer producer organizations, manufacturers to understand product value chains. The team also conducted surveys for better understanding of the value chain components in terms of inputs, waste management strategies etc.



3.2 Potato value chain in Chhindwara

Potato has been declared as Chhindwara's product under the ODOP scheme. Large parts of the district are engaged in contract farming with FMCG companies.

Chhindwara has favourable soil conditions to grow potatoes of high market value. The specialty of Chhindwara potatoes are that they achieve maturity at 65 days, contain less sugar, are harvested in 65-75 days, when at raw stage i.e. 70% (best for chips). The district also faces power outages of 4 to 6 hours in the summer months, increasing dependency on generator sets. The declining ground water table in this region- earlier at 400ft now at 1100ft- has forced farmers to install tubewells in their farms.

Chhindwara currently lacks processing plants for potato and hence the entire production is sent outside the district.

The details of the potato value chain in Chhindwara are below:

- **Productivity – 8 to 10 ton per season**
- **Input cost – INR 75,000 per acre**
- **Output cost – INR 1.10 to 1.20 lakhs per acre**

5000 MT - 3/4 DEG C		
1600 MT FMCG seeds for contract farming	1600 MT Table potato by local farmers	1600 MT Mahua, Tamrind, Jaggery

Soil Preparation:
Weed cleaning, sowing seeds while infusing pesticides

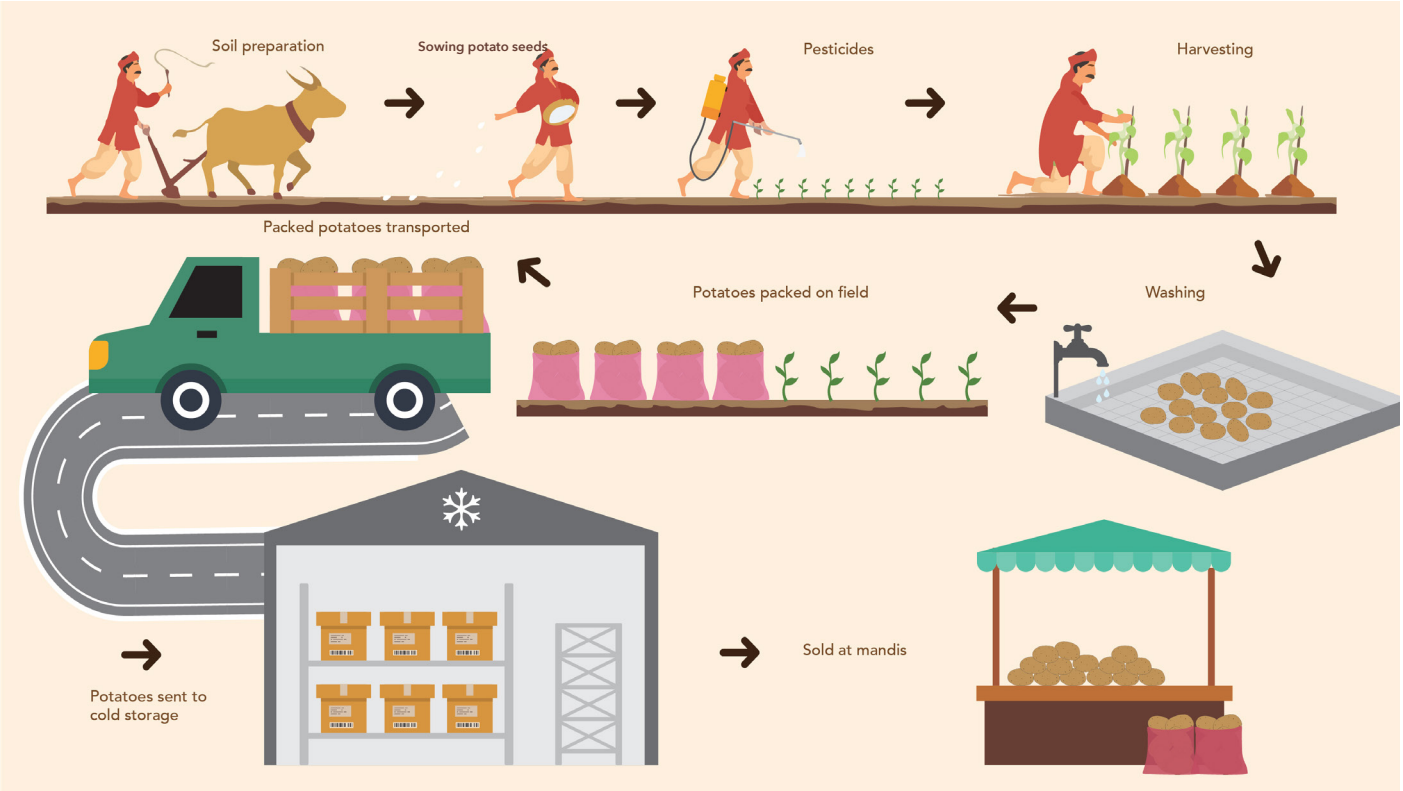
Harvesting potato and selling

1st September

Watering, spray of pesticides and fungicides, mulching

31st October

Contract farming



Details about the cold storage facility:

USAGE

- Part of the cold storage is utilized by local farmers and rest is used as a storage facility for FMCG companies

- The farmers are charged INR 2.3 per kg, irrespective of the number of days, for storing their produce.

ENERGY CONSUMPTION

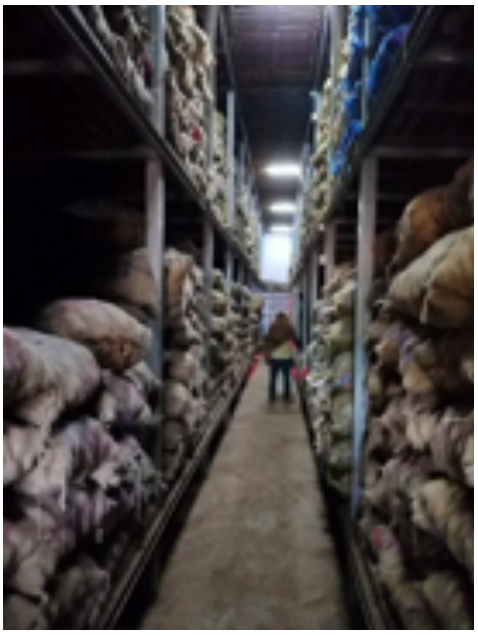
- The average electricity bill of the cold storage goes up to INR 2.5 lakhs per month for the summer months, and is INR 1.50 - 1.75 lakhs per month during cooler months.

FUTURE PLANS

- Set up a processing plant to deliver value added products

- Install solar rooftop PV in hybrid mode to cater to frequent power outages and increasing electricity bills

- Switch to electric haulers for goods transport to nearby mandis and regions when appropriate charging infrastructure network comes up



Summary of Processing and Cold storage units in Chhindwara

PROCESSING UNITS IN CHHINDWARA

- 1 spices park, established by the Ministry of Commerce, currently semi - operational. Two integrated packhouses (500 metric tonnes capacity each), funded by Agricultural and Processed Food Products Export Development Authority (APEDA) and constructed by National Agricultural Cooperative Marketing Federation of India (NAFED). Both are non-functional
- Processing unit approx. 70km from Chhindwara. Fully automated processing unit with investment worth INR 2.5 crore, manufacturing potato processed food products
- 1 Food Park

COLD STORAGE FACILITIES IN CHHINDWARA

- Total cold storage capacity of Chhindwara = 18,500 metric tonnes (3 facilities of capacity 5000-6500 metric tonnes each)

AGRI-POTENTIAL OF CHHINDWARA

- Cultivable area can be expanded by 2000ha
- High interest of local stakeholders for food processing but they are unable to compete with large players in terms of scale of business and product quality
- High potential for food processing in other products such as oranges, considering revisions in ODOP scheme to provide subsidy even for non-ODOP products
- In addition to potato, orange holds great potential in the district, with varieties like Satpura, Nagpura, Mandarin, etc.
- Medicinal plants, although hold potential in terms of yield in the region, suffer due to the absence of a proper market. Due to lack of demand and market linkages, farmers have been forced to sell at throwaway prices.
- Forming FPOs and entrusting them with procurement, storage and marketing of the products can be promoted.

Source: Interview at Krishi Vigyan Kendra, Chhindwara July 2022

3.3 Turmeric value chain in Shahdol

Turmeric has been announced as the product under the ODOP scheme for Shahdol. In comparison to other districts, Shahdol has favourable soil conditions – light and sandy- for turmeric farming, and has been traditionally grown by local farmers. Turmeric has several medicinal properties and hence is highly recommended for daily use. Also, a ready market in terms of medicine manufacturing companies is available in Indore, wherein Pithampur SEZ hosts several pharmaceutical companies. The types of Haldi used for sowing in this region are Basith haldi and Jawli haldi (desi variety) and Sonia haldi and Sukhana haldi (improved variety). The uses of these varieties range from cooking to medicinal usage, especially black haldi is of great value for medicinal use.

The team visited Beohari block in Jaisinghnagar at Shahdol, where they interviewed farmers, as well as the owners of a haldi processing unit to map the turmeric value chain below.

Soil Preparation:
Weed cleaning, sowing seeds

15th May

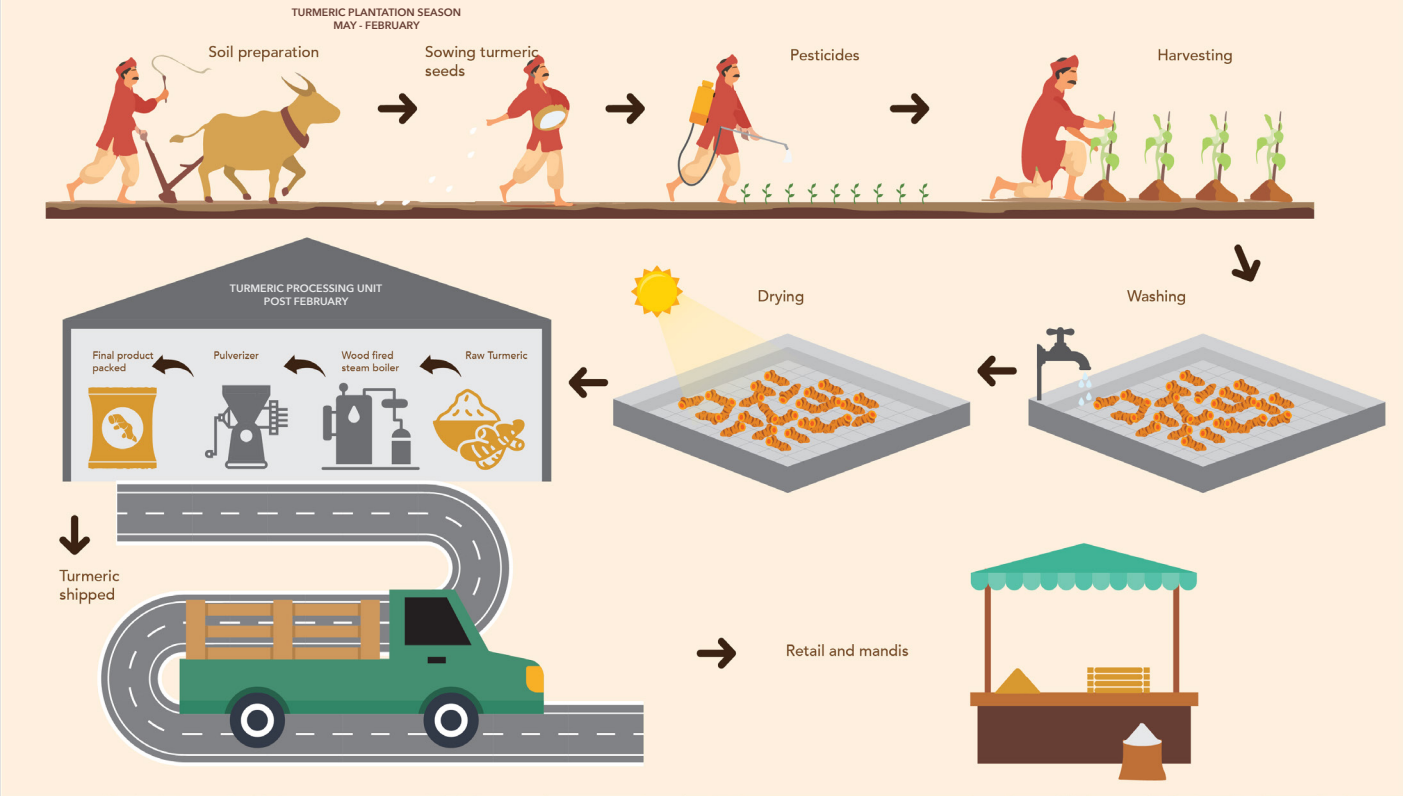
Spray of pesticides and fungi-cides, while nurturing turmeric plats, mulching

Crop cutting

November

31st December

Harvesting turmeric and processing



1 Quintal = 100 kg
1 Hectare = 247 Dismil (decimal)

INPUTS TO TURMERIC PLANTS

Fertilizer	Cowdung Urea 10*10 =100 DAP 10*30 = 300
Pesticide	Rejent GR 1kg - INR 120
Fungicide	Mancozeb - INR 100 Carbendazim - INR 150

Buy: INR 18/kg **Labour cost: INR 20/kg** **Sell: INR 110 - 120/kg**

Raw Turmeric

Wood fired steam boiler

1 HP

Pulvizer

4/5 HP

Turmeric

4-5 quintal turmeric
4 hours per batch

Based on research conducted in the prior phase of the project as well as feedback from stakeholders, this report contains:

Key takeaways from farmer interviews

Dependency on diesel pumps for electricity as bureaucratic process is longer and the current solar pump scheme does not support marginal farmers who own lands less than 1 acre

The ground water table is declining and every farm has installed tubewells

Younger generations are still inclined towards agriculture, but migration trends are evident to Surat, Raipur, Punjab, Maharashtra

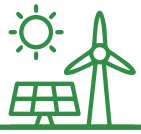
Farmers do have access to bank loans, only 10% farmers own Kisan Credit Cards

There is local demand for a food processing park at the district level

Market linkages need to be established, as farmers do not get a reasonable price for the quality of turmeric grown

Key takeaways from interview with turmeric processing unit

Currently owns 20 acres of farm area (used for turmeric and lemon grass cultivation). Expansion plans include cultivation of black turmeric, encouraging more farmers to associate with him byproviding the raw turmeric cultivated in their fields while assuring them a fair price and exporting turmeric powder with proper support as USP for the powder beingits purity through wholly organic nature of farming



Technology interventions planned include installing 1 HP solar pump for water circulation in case of a power failure; to scale up usage of renewable energy for processing and packaging units; to scale up processing unit, a fully automated assembly line for packaging and branding; to setup cold storage facility under the ODOP

Source: Interview of Haldi processing plant owner, July, 2022

3.4 Mango value chain in Umaria

The team visited owners of the mango orchards in Siddhi and Umaria. The orchards here are decades old. However, they have not been explored to commercial scale due to the properties of the fruit. The mangoes here have large kernels and hence it is difficult to extract pulp.

Locals here use mangoes for self-consumption and only a limited volume is taken to the mandis for sale. Women in the community make aachar, muramba and aamchur powder for home use.

Key takeaways from farmers, scientists in Umaria

Mango occupies 3rd rank among other crops in terms of acreage in the district

Local varieties are grown, which are not appealing commercially as the seeds are too large, resulting in less pulp

There is no mango processing plant or similar facility in the district despite it being selected under the ODOP scheme

Better varieties grown in neighboring districts which could be promoted, e.g.; Sunderja in Rewa district

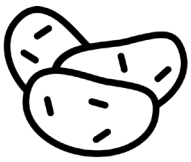
Source: Interview of Head Scientist, Krishi Vigyan Kendra, Umaria

3.5 Commercial scale medicinal

The team studied the potential for growing medicinal plants such as Ashwagandha, Kalmegh, Tulsi, Shatavari etc. These medicinal plants grow naturally in forest tracts and locals gather the produce which is mostly sent to other districts for processing. The medicinal plants are abundantly found in these regions, helping the tribal communities to earn on a smaller scale as forward market linkages are currently absent. All five selected districts are originally tribal areas, which come under the Integrated Tribal Development Agency (ITDA). These regions have huge potential for introduction of commercial farming of these crops as demand is high, with renewed impetus on organic and ayurvedic products. However, these products are not part of the Government's ODOP scheme. And given that these medicinal plants are currently harvested from forested areas, more study will be required on suitable areas for cultivation that do not destroy forested habitats or affect traditional rights of tribals to collect minor forest produce.

3.6 Summary of observations from field visits

A snapshot of observations from site visits related to prevalence of farming, post-harvest processing infrastructure and market linkages is below:



POTATO

- Contract farming implemented with FMCG companies, hence production on commercial scale
- Cold storage facility available locally
- Absence of processing units at district level

TURMERIC

- Farmers lack forward market linkages and hence production not at commerial scale
- Absence of cold storage facility
- Processing plants at nascent stage, people prefer grinding turmeric at home

MANGO

- Locals own orchards for decades, but miss out on commercial scale market opportunities
- Absence of cold storage facility
- Inspite of being declared under the ODOP scheme, district lacks processing units

Based on field visits and research on the districts' techno-economic profile, a brief SWOT analysis of the districts is below:

STRENGTHS

- Districts have suitable agro climatic conditions to boost agricultural potential
- Some crops (e.g. potato) have established contracts, bulk buyers, cold storage

WEAKNESSES

- Intermittent electricity supply and low ground water levels
- Few formal mandis, limited forward market linkages
- Few food processing units and cold storage

OPPORTUNITIES

- Cold storage facilities and processing units at community level could boost farmer income
- Conditions suitable for shift to renewable energy
- Training and capacity building programmes could lead to emergence of new value added products and services
- Better implementation of existing Government programs for solar pumping etc
- Growing medicinal herbs on degraded land is not part of ODOP, but could be promoted given the conditions

THREATS

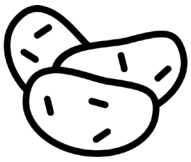
- Impact of falling water table
- Impact of climate change on farmers

3.7 Proposed interventions

Based on the site visits, surveys and interviews conducted on ground, we have proposed interventions for three product value chains. The interventions proposed are planned to suit other crops and produce of the region, having larger impact and boosting value added products.

- **Potato, is an established product, because of contract farming and the overall large scale productivity from the region.**
- **Turmeric, still in an early stage, but huge potential can be tapped foreseeing the importance and value of the product.**
- **Medicinal plants, currently at nascent stage, can explore commercial markets, benefitting the locals in terms of finance, small scale businesses.**

The proposed interventions mapped through discussions are below:



POTATO

- Well established value chain
- Contract farming by big players
- Other crops to be focused are Maize, Oranges, Tomatoes

TURMERIC

- FPOs plan to set up integrated plant for processing and packaging
- Forward market linkages missing
- Govt. sponsored subsidy scheme available, major deterrent is availability of 5 acre land

MEDICINAL PLANT

- Huge potential for commerial use farming as favorable weather and soil conditions
- Huge demand with renewed impetus an organic and ayurvedic products

PROPOSED INTERVENTIONS

- Cluster level solar powered cold storages
- Rooftop solar + Vertical axis wind turbines
- Agrivoltaics
- Electrifying freight transport with installation of charging infrastructure
- Financial packages
- Provision of buy back contracts

The proposed interventions include provision of cluster level solar powered cold storage facilities to boost longer shelf life of products. On ground energy generation can be catered through combination of rooftop solar PV and vertical axis wind turbines. Introduction to electric vehicles with adequate charging network will help achieving the state targets under the EV policy. Proposal of agrivoltaics, especially on farms growing medicinal plants, will help in production of solar energy and medicinal products. The technologies, their costs, benefits are described in

4. TECHNOLOGY INTERVENTIONS AND STANDARDISED PACKAGES

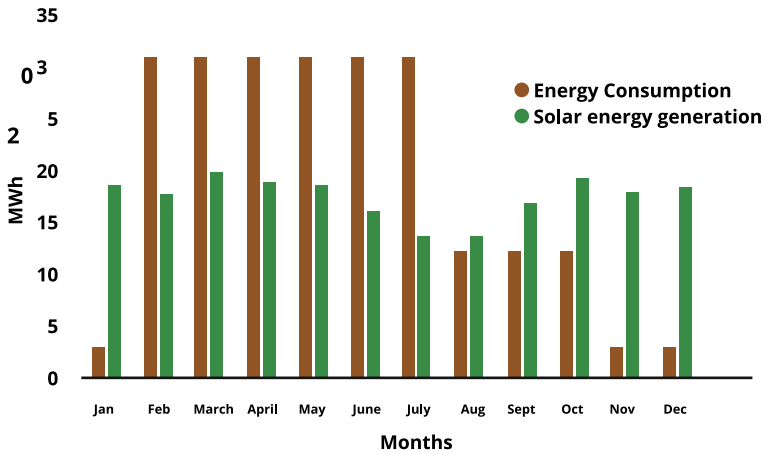
This chapter covers the technologies, costs, benefits for the following RE and EE interventions:

- Rooftop solar PV – large and medium scale with vertical axis wind turbine
- RE based distributed cold storage
- Solar dryer
- Low-cost cooling options
- Agrovoltaics
- Freight EVs

4.1 Rooftop solar PV for large cold storage plant

The team visited a cold storage plant in Chhindwara with capacity of 5000 MT, a connected load of 111.15 kW and a rooftop area of 1946 sq m. Chindwara has an average solar irradiance of 5.44 kWh/day/m2. A solar rooftop system of 134 kW has been designed to meet energy needs for this cold storage plant in three periods: pull down (100% cold storage used), holding (40%)

Based on the existing electricity bill and system analysis (details in Annexure I), the figure below shows the electricity consumption and solar generation potential. In pull down period, the storage requires grid power, while in lean and holding periods, the excess solar energy generated can be sold back to the grid under a net metering arrangement with the utility.Based on the existing electricity bill and system analysis (details in Annexure I), the figure below shows the electricity consumption and solar generation potential. In pull down period, the storage requires grid power, while in lean and holding periods, the excess solar energy generated can be sold back to the grid under a net metering arrangement with the utility.



Source: MP Ensystems research 2022

The financial parameters of the installation are below. The calculations do not include tax benefits and reduction in electricity bill through net metering.

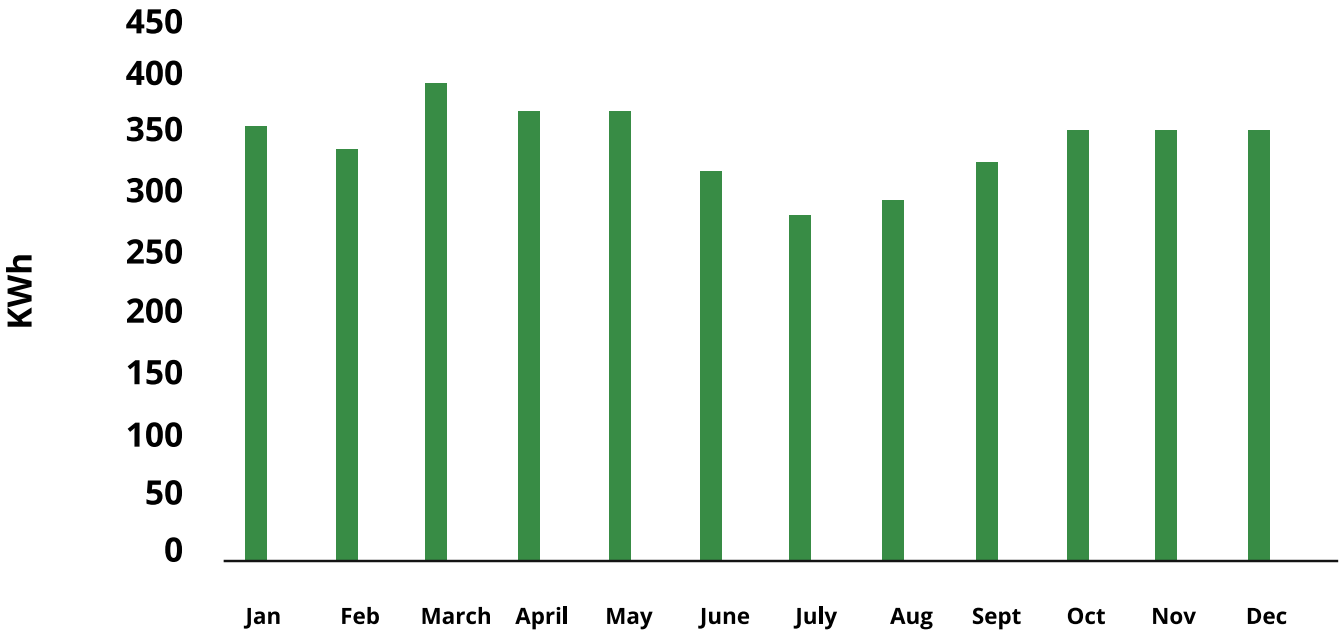
Capital investment, INR	87,35,304
Annual electricity saving (1st year), INR	13,95,075
Annual O&M, INR	1,12,500
Income tax rate, %	30
Discount factor %	10
Debt %	75
Equity %	25
Interest rate %	11
Loan amount, INR	65,51,478
Loan Period, years	7
Equity, INR	21,83,826
Discounted Payback Period, years	11.8
NPV @ 10% discount factor, INR	30,77,781.73
IRR, %	18

After accounting for tax saving, the financial performance of the project improves significantly, with discounted payback period reducing to 7.4 years, which can be favourably compared to the product life of 25 years.

Apart from the financial benefits of rooftop solar, using clean energy for cold storage plant helps in reduction of GHG emissions. Installation of solar rooftop system on the Chhindwara cold storage plant is expected to result in reduction of 3,629.8 tons of GHG emissions in 25 years.

4.2 Rooftop solar PV for small haldi processing plant storage plant

The haldi processing unit in Shahdol currently requires approximately 11 kWh daily for lighting, cooling, processing. The area receives average solar irradiation of 5.5 kWh/m2/day, and a rooftop area of 30 sq.m will be required for setting up a 3 kW PV system. Monthly energy consumption is assumed to be constant throughout the year. A 3kW solar rooftop PV system would lead to the following generation as shown in the Figure 3. storage requires grid power, while in lean and holding periods, the excess solar energy generated can be sold back to the grid under a net metering arrangement with the utility.



The financial parameters of the installation are below.

Cost of plant without subsidy, INR	1,23,538
Interest rate, %	12
Loan period, years	5
Debt (80%), INR	60,000
Equity (20%), INR	14,123
Annual debt repayment, INR	16,644
IRR, %	21%

The IRR calculated does not include the 40% subsidy available for such solar PV installations. In case the haldi processing plant is not operating, the excess power from solar PV rooftop can be used for other agricultural activities.

Supplying power using a solar PV will lead to saving in 80 tons of GHG emissions in 25 years of lifetime of solar PV system

4.3 Rooftop vertical axis wind turbine

A VAWT is a type of wind turbine in which the main rotor shaft is set perpendicular to the wind while the main components are located at the base of the turbine. This allows the gearbox and generator to be located close to the ground, which makes the structure stable. VAWTs does not require wind sensing and yaw control as the axis is perpendicular to the wind flowing from any direction.

The table below shows the estimated annual energy generation from a VAWT in Chhindwara..

Month	Average wind speed	Monthly energy Generation, kWh
Jan	1	47.8
Feb	2	95.7
March	2	95.7
April	3	143.5
May	5	239.2
June	5	239.2
July	5	239.2
Aug	4	191.3
Sept	3	143.5
Oct	1	47.8
Nov	1	47.8
Dec	1	47.8
Annual Generation		1578.4

Source: Meteoblue, 2022

The average cost of 1 kW VAWT is INR 50,000 and the feasibility of the system depends on suitable wind speeds.

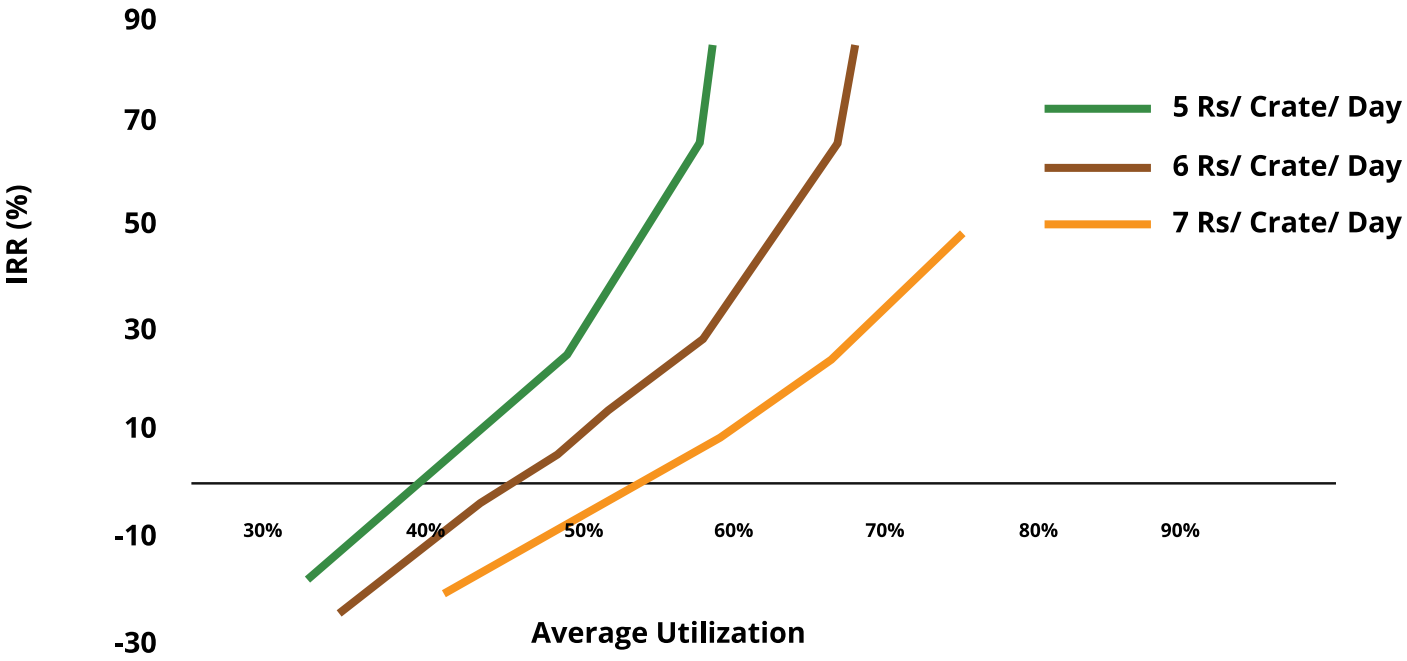
The VAWT can be combined with a rooftop solar PV system in regions where wind speeds are suitable, to increase generation capacity, reduce intermittency (by harvesting wind power at night and solar power during the day), and improve the resilience of the system to power outages. In Annexure 1 we estimate the return on installing a Rooftop Solar PV system + VAWT for a large cold storage facility.

4.4 RE based distributed cold storage

Solar-based distributed cold storage systems ranging from 5-20MT capacity can be installed at the at the community level. This system can store 5000 -6000 kg of farm produce at desired temperature. Cold storage as a service can be provided by charging an amount per kg for storing farm produce for a day in cold storage. The financial analysis is below:

Capacity, MT	5
Cost, INR	12,10,000
Annual maintenance, INR	1,50,000
Life of the product, years	10
Subsidy, %	30

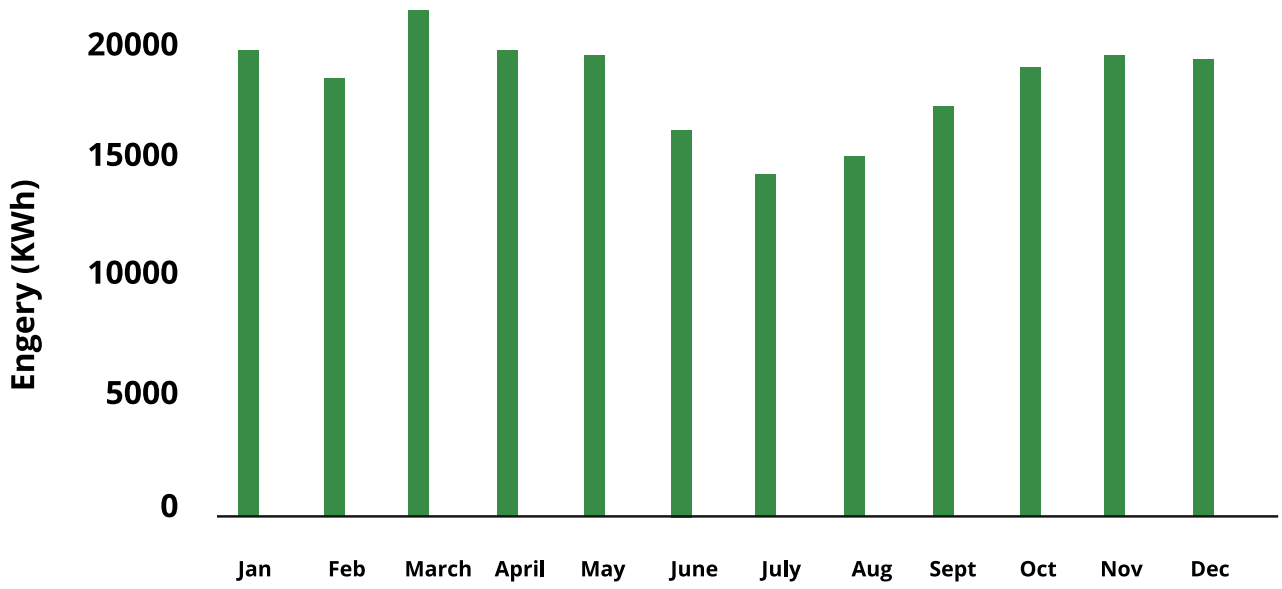
The farmer or cooperative installing this system will receive revenue from daily fees. The chart below shows the IRR, considering different rates with variation in average utilization of system.



Source: MP Ensystems Research 2022

4.5 Agrovoltaics

Agrovoltaics is the concept of installing solar PV panels on farmland to increase the land efficiency. Enough space is provided between two PV strings which enable movement of people and also space for growing crops. The revenue generated from selling energy generated from the solar panels helps in increasing the land productivity. A solar PV system of 144 kW capacity can be installed on 1 acre of farm land with enough space provided between two PV strings for movement of people and cultivation of crops. The system below is simulated for Shahdol, Madhya Pradesh to estimate the energy generation over 25 years.



Source: MP Ensystems Research 2022

Key parameters are below:

Agricultural land, acres	1
Solar PV capacity, kW	144
Investment, INR	72,00,000
Annual generation (1st year), kWh	215477
LCOE, INR/ kWh	1.41
Simple payback period (considering selling of electricity at 4 INR/ kWh), years	8.35

Levelised Cost of Energy (LCOE) for electricity generated from the agrovoltaic plant is very low (1.41 INR/kWh) as compared to electricity tariff (4 to 5 INR/kWh). This low cost generated energy can be supplied to residential and agricultural consumers in rural area where there is an issue of grid availability and frequent power outages.

The agrovoltaic system can be set up on degraded revenue land controlled by village panchayats. Medicinal plants can be grown on this land under contract farming, to generate additional revenue.

4.6 Solar dryer

Solar dryers are used to eliminate the moisture content from crops, vegetables, and fruits. The solar dryer consists of a box made up of easily available and cheap materials. The top surface of the dryer is covered by transparent single and double-layered sheets. The inside surface is black to absorb the incoming solar radiation. Since the box is insulated, the temperature inside the box is raised. The air is ventilated through the small holes at the top of the box. The air inside the dryer is circulated by the small fans which are operated by small solar panels. No external energy is required for operation of the solar dryer. Solar dryers come in capacities ranging from 20kg to 100kg. Solar dryers are cost-effective, reduce drying time and keep out impurities.

Tomato producers can use solar dryers to reduce waste and process the product at a time when there is a glut in the market and prices fall. The example below shows the benefits and costs of using a solar dryer for a farmer producing 10 tonnes of tomatoes.

Cost of dryer, INR	34,000
Capacity, kgs	40
Dimensions, m2	6
Quantity required for 1 kg of dried product, kg	10
Market value of fresh product, INR/ kg	25
Market value of dried product, INR/ kg	1,800
Number of solar dryers required	4
Simple payback period, years	1

Given the higher return on sales of dried vs fresh tomatoes, investment in a solar dryer can yield a quick return to the farmer, reduce waste and allow farmers to diversify their income streams.

Success story: drying chillies using a solar dryer

In Chiplun, a small village in Maharashtra's Ratnagiri district, Smitha Jadhav, a housewife turned CEO started a company selling dried spices. Drying chillies and other spices is a lengthy process. When Ms. Jadhav turned to solar dryer technology, the drying process for chilli which usually takes 3 days was completed in just 4 hours, with no change in its colour or taste. Since installing a solar dryer for her operations, her sales within a couple of months have touched the sales she used to achieve in a whole year. Her products are now being shipped to Maharashtra's major cities, with orders even coming from Gujarat, Karnataka, and Madhya Pradesh. The solar dryer has been instrumental in helping many small farmers and agri-entrepreneurs grow their business.

Source: Raheja Solar, 2022

4.7 Low cost cooling: vegetable cooler

Small farmers face problems due to unavailability of cost effective distributed cold storage systems to store their daily agricultural produce. Due to the lack of cold storage, farmers end up selling vegetables and fruits at lower rates in peak harvesting seasons, in many cases the vegetables are thrown as waste.

There are simple yet effective cold storage systems that work on the principle of evaporating cooling. The system can be easily built with easily available materials and does not require any external energy for its operation.

Figure 7: Low-Cost cooling using Subjee Cooler, developed by IIT Bombay students

Source: Rukart technologies

4.8 Freight EVs

In rural areas, efficient transportation of agricultural goods from farm field to mandis play an important role in farmers livelihood. The recent trend of increase in fuel prices can impact the efficiency and cost of transportation of farm goods, which can adversely impact farmers revenue.

The capital cost of electric vehicles is higher than their Internal Combustion Engine (ICE) counterparts, however the operating cost of electric vehicle is substantially lower than ICE vehicles, as they use electricity for charging, which is cheaper than conventional fuels. Total cost of ownership per km is analyzed to understand the feasibility of electric vehicles for freight transportation.

E-3 Wheeler

Vehicle type	E- 3W	CNG – 3W	Petrol – 3W
Capital cost	3,66,906	2,40,000	2,40,000
Fuel cost (INR/km)	0.6	1.65	3.98

As the fuel cost for the vehicle is low, with higher daily average distance covered by the vehicle, total cost of ownership (TCO) for E-3W becomes lower than ICE 3W.

Daily average distance	E-3W (With fame II subsidy)	E-3W (without subsidy)	Petrol 3W	CNG 3W
50 km	3.42	3.99	4.12	3.71
100 km	1.82	2.1	2.8	2.32
150 km	1.28	1.47	2.36	1.86
200 km	1.02	1.16	2.14	1.63

E-LCFV

Similar analysis is done for the Light commercial freight vehicles (LCFV) segments, Average TCO is calculated for different type of LCFV by fuel type of average milage of 150 km. E-LCFV gives better TCO (23% less) as compared to Petrol and diesel vehicles and is in similar range as compared to CNG vehicles.

Type of vehicle	**E-LCFV**	**Petrol - LCFV**	**Diesel - LCFV**	**CNG - LCFV**
TCO (INR/km)	8.54	11.12	11.76	8.96

Apart from being economical feasible, electric vehicles have zero tailpipe emission and can contribute towards reducing the GHG emissions from transportation sector.

Additionally, there are opportunities to set up freight EVCI corridors in MP, given its central location. For instance, Chhindwara sends agriculture and horticulture produce along with coal by road to Indore and to Nagpurin Maharashtra. That makes the Indore-Nagpur national highway corridor, an important one in terms of freight movement. Setting up EVCI for freight vehicles along this and other important corridors in the state will help in promoting electrification of the state's freight fleet, reduce tailpipe emissions and promote employment in EV, EVCI and related sectors.

4.9 Summary

The interventions proposed are summarised in the table below. The GHG reduction and reduction in energy costs refer to the system specification in column 3.

Table 2: Summary of technological interventions, beneficiaries with specifications

Intervention	Direct eneficiaries	Specifications	GHG reduction, tCO2	Reduced energy cost/ increased farmer income INR	Employment generation opportunities
Rooftop solar PV for large cold storage plant	Owners of existing large cold storage facilities for crops such as potato	134kW solar rooftop system	MP Government budget	MP Government budget	Employment in food processing, packaging, transportation of existing farm produce
Small rooftop Solar PV	Setting up processing for small and medium farmers of turmeric	3 kW solar rooftop system	Existing MP Skill Development Mission funds; ITI and other institutes; Private sector sponsorship	Existing MP Skill Development Mission funds; ITI and other institutes; Private sector sponsorship	Employment in producing, processing, packaging and transporting new farm produce
Vertical axis wind turbine	For small medium and large operations of processing, cold storage	3kW turbine costs INR 50,000		Depends on wind speed at the location	Opportunities for women's SHGs in food processing

RE based distributed cold storage	For large facilities or at community level, eg at district mandi	5MT capacity Cost INR 12,10,000 Annual maintenance INR 1,50,000	56 over 10 years	Net revenue depending on utilisation rate and rate of renting space to other farmers	Employment in RE and EE equipment installation and maintenance
Agrovoltaics	For degraded land, at community scale	144 kW system on 1 acre of land Medicinals and aromatics planted between the solar panels Cost of PV system INR 72,00,000	3698 over 25 years	215477 kWh energy generated annually, which can be sold or used. Additional income from crops	Employment in EVCI operation and maintenance
Solar dryer	Small and medium farmers of chilli, tomato	40 kg capacity Cost INR 34,000		INR 3,10,000	
Low-cost cooling	Small scale farmers of vegetables	100 kg capacity Cost INR 28,000		Can raise farmer income by 30%	
Freight EV	Medium and large scale farmers of all crops	E 3 wheeler cost INR 3,66,000	16 over 10 years (100 km / day)	Depending on distance covered, total cost of ownership can be less than ICE vehicle	

Source: MP Ensystems Research, 2022

The table below contains estimates of the benefits of the above technologies if they are applied across the state. Assumptions are listed below the table.

Table 2: Summary of technological interventions, beneficiaries with specifications

Intervention	Beneficiaries	Technical Potential	Economic Potential	Market Potential	Cost, INR crore	GHG Reduction, tCO2	Simple payback on investment, years
Rooftop solar PV for large cold storage plant	302 cold storages with total capacity of 12,93,574 MT	40.77 MW	8.15 MW	0.82 MW	5.3	22,082.7	9.6
Roofttop PV for small haldi processing plant	300 haldi processing plant with 3 kW of rooftop PV	0.9 MW	0.18 MW	0.02 MW	0.1	3,557.9	7.4
Solar dryer	14,98,750 agri households	59,95,000 units	11,99,000 units	1,19,900 units	407.7		0.3

RE based distributed cold storage	At 259 mandis	25.90 MW	5.18 MW	0.52 MW	12.5	5,801.6	3.1
Agrovoltaics	1,40,95,000 ha of degraded land and wastelands	5,015.5 MW	1,003.1 MW	100.3 MW	501.5	25,75,990.1	8.4
Low-cost cooling option	14,98,750 agri households	14,98,750 units	2,99,750 units	29,975 units	83.9		0.6
Freight EVs	5,99,500 agri households	5,99,500 units	1,19,900 units	11,990 units	438.8	1,91,840.0	4.7

Source: MP Ensystems Research, 2022

Assumptions:

- **Solar rooftop PV- applied to existing cold storages in MP. Data source: Ministry of Agriculture and Farmer Welfare, 2020**
- **Connected load at each cold storage is 115 kW (135 Solar PV DC capacity, 100 kW AC capacity)**
- **There are 59,95,000 agri households in the state**
- **25% of households with 4 solar dryers each**
- **Agrovoltaics on degraded and wastelands, data source ICAR 2010 . 0.1% of land is covered by agrovoltaics**
- **20 solar based small cold storage systems with solar capacity of 5 kW installed at each mandi**
- **25% households with 1 cooling system each, annual farmer income is INR 1,50,000**
- **10% of households with 1 E-3W each**
- **Technical potential is estimated as RE in MW that can be generated, based on farming households, existing solar insolation, number of farms in MP**
- **Economic potential is based on costs and benefits of interventions. It is estimated at 20% of technical potential at this stage.**

- **Market potential depends on availability of products, policy support, awareness. It is estimated at 10% of economic potential. As the market develops, more interventions will become available, and the economic and market potential are expected to increase.**
- **The benefits or costs of the table above cannot be added, as some interventions are substitutes of each other.**

While the benefits of reduction in GHG emissions can be estimated for technologies where RE is used in place of conventional energy, the benefits of reducing costs, raising farmer income, creating employment opportunities, improving health outcomes, providing income-generating opportunities to disadvantaged communities will need to be estimated by conducting detailed surveys after pilot implementation.

4.10 Standardised packages

The selected interventions have been organised into 3 packages, that apply to different categories of farmers in MP. The advantages of creating standardised packages are:

- **The proposed interventions vary in their extent of reducing GHG emissions, generating income and employment and in their payback periods. Combining them into packages would lead to improved outcomes across these parameters.**
- **Creating a package of interventions helps beneficiaries become aware of the options, benefits, costs that apply to their situation, without extensive technical know-how**
- **Banks can provide loans (with interest rate subventions), with guidelines on technologies, costs, suitability to farm sizes, expected returns on investment, removing a hurdle to financing RE in rural areas**
- **If the Government provides incentives to rural recipients, creating streamlined packages reduces the cost due to bulk purchase and simplifies implementation and evaluation**

The proposed interventions are based on a study of the conditions of 5 districts in MP. Additional interventions can be proposed and added to the packages. These packages are expected to become part of a Government policy, along with financial incentives, training and awareness campaigns.

Description	Interventions
1. Established For crop grown at large scale with established value chain eco system, e.g. potato	Installation of cluster level solar powered cold storages (5MT capacity), rooftop solar PVs (170kW*) combined with VAWT where suitable, solar dryers, Freight EV
2. Early For crop grown at small scale with limited value chain, with some state support such as designated ODOP eg: turmeric	Installation of new processing plants with cluster level solar powered cold storages, access to solar pumps, solar dryer, vegetable cooler, additional financial assistance and forward market linkages, training
3. Nascent For crop grown at very small scale, sold locally without any value chain or supporting eco system e.g. medicinal plants	Solar dryer, Agrivoltaics along with medicinal plants, forward market linkages, provision of buy back contracts and financial assistance, training

Source: MP Ensystems Research 2022

5. FINANCE MECHANISMS

Some of the main central government schemes that finance post-harvest storage and processing are:

5.1 Central government financing

1. Agricultural marketing infrastructure (AMI)

The Agricultural Marketing Infrastructure (AMI) is a sub-scheme of the Integrated Scheme for Agricultural Marketing (ISAM), which is aimed at the holistic development of the agricultural value chain. It focuses on the linkage of post-harvest value chain including promotion of value addition and processing at the farmers level to enhance their income by selling more marketable and processed products in the market. One of the stated objectives of the scheme is to promote innovative and latest technologies in post-harvest and agricultural marketing infrastructure. The scheme provides for 25% subsidy, subject to a maximum subsidy of INR 25 Lakhs for the installation of non-storage infrastructure .

2. Agriclinic and agribusiness centres scheme

This scheme is a component of the Sub-Mission on Agricultural Extension (SMAE). It has both training and capital support components and is implemented by National Institute for Agricultural Extension Management (MANAGE), Hyderabad and NABARD, Mumbai. The scheme envisages providing support to agri-preneurs, supporting agricultural development and creating gainful self-employment opportunities to unemployed agricultural graduates. It also proposes the setting up of Agri-clinics to provide expert advice and services to farmers on various agricultural technologies and Agri-Business Centres that are commercial units of agri-ventures established by trained agriculture professionals.

NABARD provides loans for creating infrastructure under its Warehouse Infrastructure Fund. It also provides refinance to institutions that lend to the agriculture sector.

National Institute of Agricultural Extension Management (MANAGE) provides training to eligible candidates and motivates them for setting up of Agri- Clinics and Agri-Business Centres. The eligible trainees can avail loans up to INR 20 lakhs for an individual project and to INR 100 lakhs for a group project. NABARD provides refinance assistance to the lending institutions.

3. Agriculture infrastructure fund

The financing facility under the scheme is created to mobilize a medium - long term debt finances facility for investment in viable projects for post-harvest management Infrastructure and community farming assets. One of the objectives of the scheme is to facilitate investments in logistics infrastructure to reduced post-harvest losses. the fund has a corpus of **INR 30,000 crores** for each financial year. Under this, the central government provide support for interest subvention and credit guarantee fee as well as providing the administration Cost of Project Monitoring Units. Loans are provided by

- Scheduled commerial banks
- Scheduled cooperative banks
- Regional rural banks (RRBs)
- Small finance banks
- Non - banking financial companies (NBFCs)
- Other financing entities

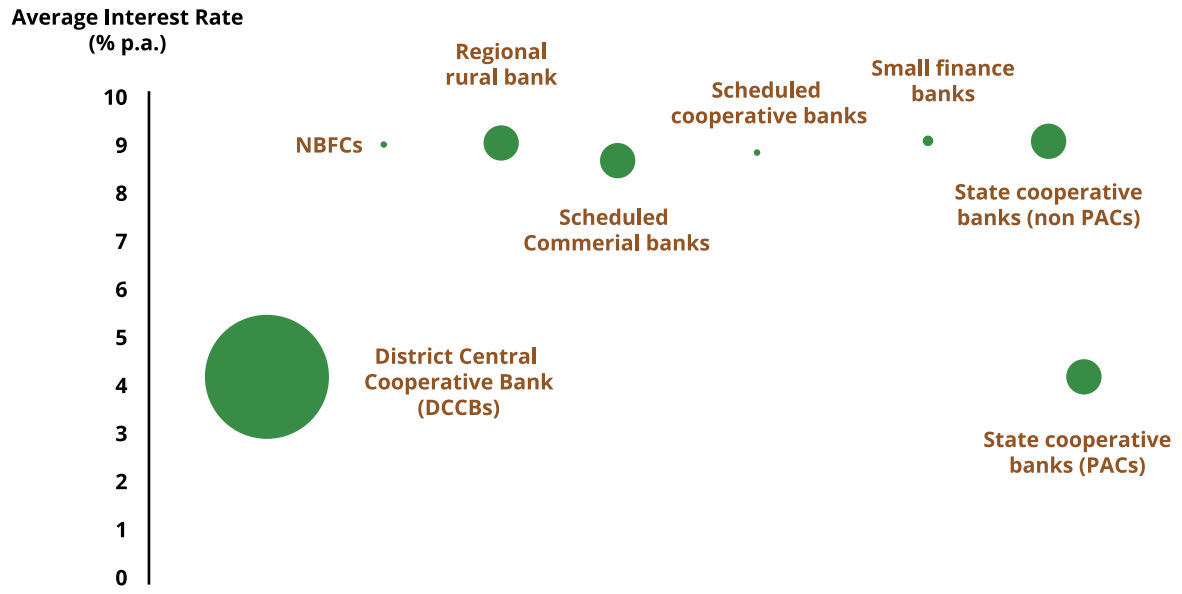
with priority to community institutions including Agricultural Credit Societies (PACS), Marketing Cooperative Societies, Farmer Producers Organizations (FPOs), Self Help Group (SHG), farmers, Agri-entrepreneurs and startups. 24% of total grants – in – aid under the scheme are kept for utilization of SC/ST entrepreneurs, while lending institutions also need to ensure adequate coverage of entrepreneurs belonging to women and other weaker segments of society.

The Agriculture Infrastructure Fund is a 10-year scheme launched in 2020 to provide

INR 1,00,000 crore

for financing infrastructure at the farm-gate, including supply chain, cold storage, processing and logistics.

The figure below shows the average interest rates offered by different categories of participating banks. The bubble size shows the number of participating banks- the largest number being the DCCBs.



The financing facility has a total corpus of INR 1 lakh crore, of which Madhya Pradesh is among the top 5 recipients of the funding at INR 7,440 crore .

4. National Horticulture Board (NHB) scheme on development of commercial horticulture through production and post-harvest management

The scheme provides for credit-linked assistance to projects related to both production related components and post-harvest management / Primary Processing related components. For processing related components, credit linked back-ended subsidy for **40%** of the total project cost is provided, with a ceiling of INR 50 lakh per project . The scheme also provides technical specifications with respect to the post-harvest management technology with requirements as follows:

- The projects assisted are either on-farm projects linked with individual projects of area expansion of commercial horticulture OR
- As a common facility for cluster of new projects of commercial horticulture.

5. Mission for Integrated Development of Horticulture (MIDH)

Under MIDH, financial assistance is provided for developing infrastructure and optimising operations of activities interlinked to post-harvest management. For the development of post-harvest infrastructure, a subsidy is provided at the rate of 35% of admissible capital cost. The funding facility is available for both public and private sector enterprises. The scheme is focused more on commercial ventures and the government assistance is linked to the bank credit availed. The scheme incentivises better practices and energy efficiencies in the post-harvest management infrastructure, including the modernisation of existing infrastructure assets.

6. Rashtriya Krishi Vikas Yojana – remunerative approaches for agriculture and allied sectors rejuvenation (RKVY-RAFTAAR)

It is a scheme of the Ministry of Agriculture and Farmers' Welfare, Government of India. It is aimed at strengthening infrastructure in Agriculture and Allied sectors to promote Agripreneurship and Agribusiness by facilitating financial aid and nurturing a system of business incubation. One of the main objectives of the scheme is to help farmers in increasing their income by encouraging productivity and promoting value chain addition linked production models. It is a Centrally Sponsored Scheme where the states and the Centre contribute in ratio of 60: 40 .

7. National agricultural development scheme

Under the nation-wide scheme, many interventions have been included for the state of Madhya Pradesh. The project provides a provision for construction of onion storage houses of 25-50 MT. The cost of construction of a 25MT storage house is INR 1.75 lakhs, the scheme provides a 50% grant of INR 0.875 lakhs. Similarly for construction of a 50 MT storage house a grant of INR 1.75 lakhs is provided. The project is applicable in all districts. Also, for expansion of vegetable area around big cities. The project covers districts of division headquarters such as Bhopal, Ujjain, Indore, Rewa, Gwalior, Hoshangabad, Jabalpur, Sagar and Shahdol.

Under the Integrated Horticulture Development Mission, a grant of

50%

on project cost up to

INR 0.25 lakh

on expansion of hybrid vegetable production is provided.

8. National medicinal plants mission

This mission is being operated under the National AYUSH Mission of the Government of India. In Madhya Pradesh, under the area expansion scheme of medicinal crops, the selected 10 districts are Ujjain, Mandsaur, Neemuch, Ratlam, Dewas, Shajapur, Agar-Malwa, Chhindwara, Harda and Rajgarh. Subsidy of 30% on the unit cost is payable on Ashwagandha, Kalmegh, Colius (Pathrachur) and White Musli.

9. Pradhan Mantri formalisation of micro food processing enterprise

It aims at enhancing the competitiveness of existing individual micro-enterprises of the food processing

industry and support Farmer Producer Organizations (FPOs), Self Help Groups (SHGs) and Producers Cooperatives along with their entire value chain. The Scheme adopts One District One Product (ODOP) approach, which provides the framework for value chain development and alignment of support infrastructure. Under this, individual micro food processing units are provided credit-linked capital subsidy at 35% of the eligible project cost with a maximum ceiling of INR 10 lakh per unit. FPOs and SHGs too are supported with a 35% grant along with credit linkage .

10. Scheme For financing agri-business projects with venture capital assistance from small farmers' agri-business consortium (SFAC)

The nodal agency for the scheme is Small Farmers' Agri-business Consortium (SFAC). The objective of the scheme is to help promote investments in agri-business projects that are dependent on agriculture and allied activities, to increase rural employment and encourage farmers to diversify into high value crops. Individuals, producer groups as well as organizations are eligible for assistance, provided the project cost is between INR 15 lakhs to INR 5 crores. A Venture Capital Assistance of 26% of promoter's equity, or INR 50 lakhs, whichever is lower, is provided under the scheme .

11. Capital investment subsidy scheme for construction/ expansion/ modernization of cold storages and storages for horticultural produce

This scheme is aimed at construction, expansion or modernization of cold storages and storages for horticultural produce to minimize post-harvest losses. Cooperatives, companies, corporations, Agricultural Produce Marketing Committees(APMC's), Agro-Industries Corporations and Growers' Associations, etc are eligible for assistance under the scheme. Under the scheme, back-ended capital subsidy is available from National Horticulture Board .

5.2 MP government schemes

1. Medicinal and aromatic crops area expansion scheme

This is a scheme of the Horticulture and Food processing department of Madhya Pradesh. Under the scheme, the farmer is given a subsidy of 20 to 50% crop-wise for expanding the area of medicinal and aromatic crops. A farmer can avail benefits for 0.25 hectares upto 2 hectares of area expanded for the crops under the scheme. The crops covered include Amla, Ashwa Gandha, White Musli, Sarpagandha, basil, Kalmegh.

> **Though medicinal and aromatic herbs are not part of ODOP, farmers can receive support from the MP Government under the Medicinal and Aromatic Crops area expansion scheme.**

2. Special scheme for enhancement of storage infrastructure

Introduced by the Horticulture and Food processing department of Madhya Pradesh the scheme aims to increase cold storage capacity in the state. A grant-in-Aid of 50% of the cost of cold storage with capacity upto 5000 MT will be provided, with a maximum aid of INR 2.00 crore. The scheme is implemented by district horticulture departments and all farmers are eligible.

3. Kitchen garden scheme

This is a scheme of the Horticulture and Food processing department of Madhya Pradesh Under which small, marginal farmers and landless labourers who fall below the poverty line (BPL) are distributed packets of horticultural crops like bottle gourd, lady's finger, bitter gourd, spinach etc free of cost for cultivation.

4. Spices development scheme (Minikit)

The scheme by the Horticulture and Food processing department of Madhya Pradesh provides minikits of ginger, turmeric, garlic, coriander and chilli to all districts of the state. This is done to encourage cultivation of these spices in the state.

Tumeric is one of the crops receiving support as a part of the Spices Development Scheme and Spices Area Expansion scheme.

5. Spices area expansion scheme

This is a scheme of the Horticulture and Food processing department of Madhya Pradesh. Under the scheme, there is a provision to provide 50% of the unit cost for the expansion of the area with advanced / hybrid spice crop for the farmers. The assistance is capped at a maximum of INR 10000 per hectare for seed crop and a maximum of INR 50,000 per hectare for root and tuber / rhizome crops such as turmeric, ginger, garlic. In the scheme, a farmer can be given the benefits for 0.25 hectares to 2 hectares. District horticulture departments monitor the implementation of the scheme and all farmers are eligible.

6. Farmers' training and exposure visit program

In order to make the farmers aware of the new techniques of cultivation of horticulture crops and its benefits, they are provided training by traveling within the state and outside the state. The assistance provided is as follows:

- Farmers training tour within the state: INR 1000/- per farmer per day (maximum 7 days)
- Farmers training tour outside the state INR 1500/- per farmer per day
- Exposure visits outside the state for new technology overview

7. Encouraging mechanisation to enhance horticulture production

In this scheme of the Horticulture and Food processing department of Madhya Pradesh, farmers who want to use modern machines in horticulture crops are given a subsidy of 50 percent of the unit cost subject to an upper ceiling. The grant is provided for various machinery including Potato Planter/Digger, Garlic/Onion Planter/Digger, tractor mounted sprayer, Power Operated Pruning Machine, power tiller, Power Spray Pump, et al.

8. Yuva Udyami scheme

This is a scheme of the Industrial Policy and Investment Promotion Department of Madhya Pradesh which provides the local residents of Madhya Pradesh (between 18-40 years) financial assistance to promote self-employment. Under the scheme, projects ranging between INR 10 lakhs to INR 1 crore are supported and margin money assistance of 15% (up to a maximum of INR 12 lakhs) is payable on the pilot scheme of the project.

5.3 Banking sector schemes

1. Priority sector lending by banks

For the development of the basic needs of the country, Government of Indian and Reserve Bank of India have identified certain sectors which need to be given credit on priority. Banks are mandated to encourage the growth of such sectors by providing adequate and timely credit. Currently there are 8 priority sectors, including agriculture and MSMEs. RBI mandates 40% of the Adjusted Net Bank Credit of domestic commercial banks should go for priority sector lending. Further, 18% of the Adjusted Net Bank Credit should go for agricultural lending, out of which 10% is prescribed for Small and Marginal Farmers (SMFs). Further, 7.5% of the Adjusted Net Bank Credit should go for lending to micro enterprises.

2. District lead bank scheme

The Lead Bank Scheme assigns lead roles to individual banks for specific districts. The function of the lead banks is to coordinate the efforts of all other banks, financial institutions, and other development agencies for bringing about the overall development of the districts, especially in the rural and semi-urban areas .

The State Government can partner with District Lead Banks to spearhead schemes linked to ODOP, priorities and requirements of specific districts.

The lead banks for the districts under consideration for the project are:

District	Lead Bank
Chhindwara	Central Bank of India
Shahdol	Central Bank of India
Singrauli	Union Bank of India
Siddhi	Union Bank of India
Umaria	State Bank of India

5.4 Alternate financing mechanisms

Alternate financing mechanisms are in use in different parts of the world which aim at ensuring financial assistance, while ensuring investors earn reasonable rate of returns. Such initiatives have been instrumental in attracting private investment in the agricultural sector as well. Three prominent examples of alternate financing mechanisms that are gaining ground in India are:

1. Blended finance

Blended finance channels private investment to sectors of high-development impact while at the same time delivers risk-adjusted returns. The essential idea behind blending is that a grant or grant-like contribution can be used to remove barriers to public or private investments. Blended finance can improve the risk-return characteristics of an investment by mixing capital flows with different financial and non-financial return expectations within an investment structure. Where public budgets are limited, such investment structures may help mobilize more funding from the private sector.

2. Social impact bonds

SIBs are performance-based contracts. The social impact bond model is intended to attract private investment with the promise of a commercial rate of return. Social impact bond projects improve efficiency because in such projects, risk is transferred to private investors and they have stakes in the project as their rate of return is linked to performance. The idea is that private investors and the government enter into a contractual arrangement whereby investors fund services and receive payment for "an improvement in a specific social outcome once it has been achieved". If the outcomes that have been agreed are achieved, the investors receive their capital back plus a profit margin.

Case study: blended finance for the value chain in Kenya

In Kenya, the Program for Rural Outreach of Financial Innovations and Technologies (PROFIT), envisioned for the period 2010-19 aimed to provide financing services along the value chain that could strengthen the productivity and profitability of various small-scale rural stakeholders. PROFIT involved financing by International Fund for Agricultural Development (IFAD), the Government of Kenya and the Alliance for Green Revolution in Africa (AGRA). The blended finance instruments were created so as to:

a) leverage funds for rural investment by lowering financing costs

b) inject liquidity to participating microfinance institutions to address their funding constraints and lower the cost of finance

PROFIT used concessionary development finance from IFAD and the Government of Kenya to deploy two blended finance instruments. The two financial institutions together were able to leverage about 4.75 times the original investment. It also exceeded the targets it had set for the number of farmers it reached. AFC was able to leverage its lending to reach 6.4 times the amount of the risk sharing facility amount and reach 111,563 final beneficiaries, while bringing portfolio at risk down to about 9%, compared with more than 60% pre- PROFIT. It has also received further funding from the African Bank for Development to use the same models to reach youth and technical support from UN Women.

Source: Smallholder and Agri-SME Finance and Investment Network (2022)

3. Social stock exchange

In 2021, the Securities and Exchange Board (SEBI) approved the creation of a Social Stock Exchange (SSE), to provide funds to private and non-profit enterprises working in specific fields including poverty alleviation, environmental conservation etc. Organisations listed on the SSE will be able to raise capital through equity, zero-coupon bonds, mutual funds, social impact funds, and development impact bonds. These listed organisations will be subject to social audits and will need to provide transparency, potentially improving their governance and effectiveness. Under the framework created by SEBI, the SSE is to be established under an existing stock market, such as the Bombay Stock Exchange (BSE).

4. Voluntary carbon credits market

India has announced the start of voluntary carbon credit trading in 2023, to be administered by the Bureau of Energy Efficiency (BEE). Rural value chain interventions that have low costs could be registered for carbon emission reduction certificates and these certificates may be bought by entities that have higher costs of reducing GHG emissions.

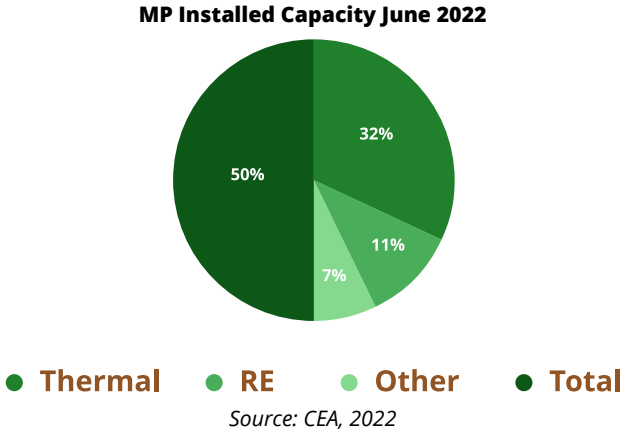
6. PROPOSED POLICY INTERVENTION

6.1 MP government roadmap in greening the rural sector

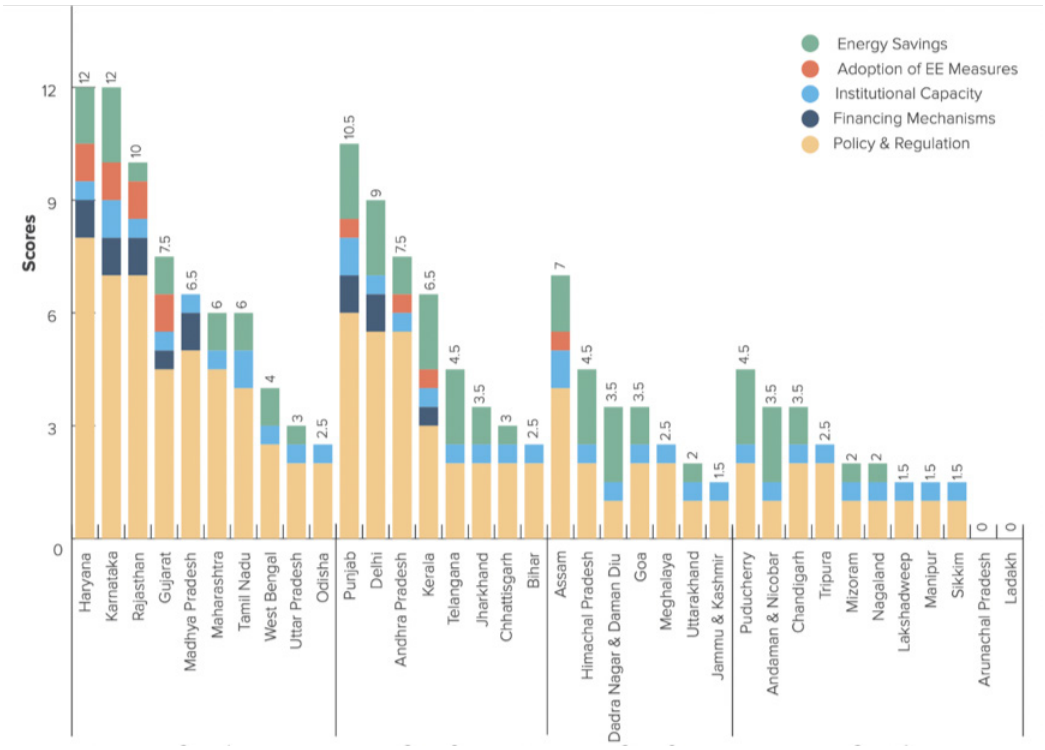
1. Agricultural Marketing Infrastructure (AMI)

Madhya Pradesh's installed capacity for RE generation stands at 24787.4 MW in June, 2022. The chart below shows that RE accounted for 5497 GW, or 11% of the total.

Under the annual State EE rating report, MP's energy efficiency performance was rated as Contender (below states ranked Frontrunner and Achiever). In the agricultural EE sector, MP ranked average on EE Policy and Regulations, financing mechanisms and institutional capacity, but had limited EE measures adopted and did not show large-scale energy savings through EE.



Source: CEA, 2022



In 2015, as part of India's State RE Capacity Addition roadmap, Madhya Pradesh was set a target of generating 12 GW of renewable power capacity by 2022, with 495 MW to come from grid-connected solar rooftop projects. Current state initiatives in EE and RE including those under the Atmanirbhar MP plan include:

LARGE SCALE SOLAR PARKS
The state has launched the process of building a large scale RE project at Agar, Neemuch and Shajapur.

SOLARIZING WATER BODIES
There are plans to build a floating solar park on the Narmada river at Omkareshwar and on the Upper Lake, Bhopal.

RE IN AGRICULTURE
The Government has targeted installation of 25,000 solar pumps by 2025.

GREEN ENERGY CORRIDOR
In partnership with Power Grid Corporation, the MP Government will set up a dedicated transmission network for RE evacuation .

INNOVATIVE RE PROGRAMS
The Government's scheme that promotes rooftop solar on health institution buildings has now been taken up by Niti Aayog for replication across the country. The government also has implemented a RESCO (Renewable energy service company) model, where solar developers can invest in installing solar PV on government buildings and earn a return from the sale of power to beneficiaries. The government also plans to build hybrid RE parks and energy storage facilities. Under the Kusum Yojana, the government will support local bodies in setting up 2 MW solar power plants and purchase electricity produced by these plants

UTILITY INITIATIVES FOR EE
In partnership with EESL, MP discoms are distributing efficient lightbulbs, providing discounts for purchasing star labelled agriculture pumpsets and have time of day (ToD) tariffs to reduce peak hour consumption .

EE IN RURAL AREAS
Under the Madhya Pradesh Energy Efficiency Improvement Investment Program, ADB provided the state with a loan of USD 400 million to improve operational efficiency of electricity distribution in rural areas, benefiting 1.4 million households .

EXISTING POLICIES

SOLAR POLICY, 2012
The policy aims at providing incentives to encourage the private sector to set up of solar PV power plants in the state.

DECENTRALISED RE POLICY 2016
The policy aims at promoting RE technology, job creation, energy security, reduce discom losses through distributed generation and reduce carbon emissions.

MP EV POLICY, 2019

The policy aims at promoting clean mobility, developing charging infrastructure and creating EV manufacturing capacity in the state.

6.2 Proposed intervention: decentralised RE in rural value chains

The state's roadmap to 2023 under Atmanirbhar MP covers physical infrastructure (including energy), governance, health and education (including training), economy and employment (including agriculture market reform). A policy or programmatic intervention in the rural value chain can become a part of the Atmarnirbhar MP process, under physical infrastructure. This is expected to fill a gap in the plan, help the state achieve its decarbonisation targets, while promoting enhanced income and livelihood in rural areas, where over 70% of its population resides. The details are below.

VISION

- **Create farm-to-fork leadership in the country by linking rural areas with urban centers**
- **Promote green rural value chains that have net zero emissions, are climate resilient and climate adaptive**
- **Create green rural employment opportunities in agriculture, manufacturing and services**
- **Enhance livelihood and employability through upskilling and reskilling of the workforce in partnership with educational institutions in the state**

TARGETS FOR PHASE I

- **Enhanced livelihood opportunities in 20% of districts through greening rural value chains**
- **Participating rural enterprises to generate 50% of energy from renewables**
- **Create a mesh of charging network for EVs in freight transport to be set up along five major agriculture/ horticulture corridors in state**
- **Entrepreneurship and skill development programs to be conducted in 50% of the districts**

PROPOSED INTERVENTIONS AND BUDGET

The table below shows the proposed interventions. In this table, government expenditure has been assumed to be 10% of technology cost, which can be implemented through bulk purchase, rebate, subsidy, interest rate subvention or any other mechanism, along with training and management costs for the first year. The source of funds is the MP state general budget.

Intervention	Govt Expenditure, INR Crore
Rooftop solar PV for large cold storage plant	0.5
Solar dryer	40.8
RE based distributed cold storage	1.3
Agrovoltaics	50.2
Low-cost cooling option	8.4
Freight EVs	43.9
Training	30
Dissemination	10
Program management	20
Total	205

During the evaluation in year 2, the management team can estimate direct and indirect benefits of the program in terms of raising income, generating employment and reducing GHG emissions. Future benefits and targets can be set accordingly.

BENEFICIARIES

• The expected beneficiaries are below

FARMERS

- Increased income from selling value added commodities
- Lowered energy cost
- Enhanced resilience to price variations, extreme weather shocks

NON-FARMING RURAL POPULATION

- Employment opportunities in food processing, RE and EE installation and maintenance

INDUSTRY

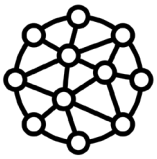
- Enhanced opportunities for trucking, logistics firms, retailers
- Opportunity in EV charging, maintenance

STATE POPULATION

- Improved connectivity between rural and urban areas
- Improved performance of state electricity utilities
- Improved air quality from reduced DG set use

BENEFICIARIES

• The expected beneficiaries are below



TECHNOLOGY INTERVENTIONS

- Prepare a suite of RE and EE interventions
- Get feedback from farmers, industry and public to improve interventions

TRAINING AND SKILL DEVELOPMENT

- ITIs, IIT, Govt training institutes to offer training in relevant areas

FINANCIAL PACKAGES

- Partner with banks, FIs, industry to provide district-wise schemes

INFORMATION DISSEMINATION

- Provide information on benefits
- Create directory of technologies and service providers

The program is expected to be led by the Farmer Welfare and Agriculture Development Department. Since inputs are required from other Government departments and agencies, an empowered group can administer the program, with members from the following ministries and departments: rural development, electricity, food processing industries, MSME, and skill development, finance. The government can also seek inputs of premier educational institutes in the state, farming, and industry representatives.

Alternatively, the government can set up a company with the objective of just transition, i.e. aiming at greening the economy while promoting the interests of weaker sections of society. The Maharashtra Government has set up MAHAPREIT (Mahatma Phule Renewable Energy and Infrastructure Technology Limited), which is currently working in the areas including setting up EVCI, affordable housing and agro processing value chains in partnership with rural women's groups. Such an entity could spearhead the program.

Interventions	Outputs	Responsibility	Source of funding
Listing technology interventions	Suite of EE, RE interventions suitable for MP agro climatic zones, solar insolation levels and local industries	MP Government to appoint consultant to study suitable EE and RE solutions	MP Government budget
Training and skill development	Training programs on EE, RE equipment installation and maintenance; EV charging and EV maintenance; entrepreneurship in green sectors;	Directorate of Skill Development to use existing infrastructure; In partnership with ITIs, IIT Indore for course development; private sector to provide inputs and participate in job placement	Existing MP Skill Development Mission funds; ITI and other institutes; Private sector sponsorship
Financial package	Loans targeting RE, EE, EVs in rural sector	District lead banks	Bank lending, with additional interest rate subventions from Government programs and donor agencies
Awareness and dissemination	Government machinery to provide information on program in rural areas through radio, TV, newspaper ads Government to host website with service providers, technologies and financing information	Rural development ministry to inform panchayats of program Government to partner with industry to host website	Website to be part financed by industry
Monitoring and evaluation	Studying the benefits, costs, effectiveness of the interventions Results to be used to modify future iterations of the programs	Nodal agency for the project	MP Government budget

Source: MP Ensystems Research, 2022

7. ROLE OF STAKEHOLDERS

There are several key stakeholders in the state that play an important role in the energy-water-food-climate nexus. These stakeholders consist of decision makers, subject matter experts, platform providers, industry experts and technology incubators.

The aim of bringing all of these stakeholders on one platform is to understand and manage these often-competing interests while also ensuring the integrity of the ecosystems. While we plan to achieve the interests of the stakeholders, we plan to create substantial impact on the ground by creating and enhancing alternative livelihood opportunities.

KEY STAKEHOLDERS

GOVERNMENT

- National - Ministry of Coal, Power, MNRE, NITI Aayog etc
- State - Dept. of Agriculture, Energy, Transportation, Rural development, Education, District Collectors, PSUs
- National Skill Development Corporation, Surya Mitra etc.

ACADEMIA, CIVIL SOCIETY & SUBJECT MATTER EXPERTS

- IIT Indore, IIM Indore, Rabindranath Tagore National University
- Jeevika, Krushi Vikas va Gramin Prashikshan Sanstha, Samarthan, Skills Art and Beyond, TARA Livelihood etc
- Subject matter experts from organizations such as CEE, iForest, Rocky Mountain Institute, Prayas, TERI etc

UTILITIES

- Madhya Pradesh Paschim Kshetra Vidyut Vitran Co. Ltd.
- Madhya Pradesh Poorv Kshetra Vidyut Vitaram Co Ltd.

TECHNOLOGY INCUBATORS

- Atal Incubation Centres (Aartech, Prestige Inspire)
- Start up ecosystem in relevant sectors

INDUSTRY & PVT SECTOR COMPANIES

- Mahindra Group, Tata Group, Aditya Birla Group, Reliance Group, Big Basket, Star Bazaar etc.

EDUCATION PLATFORM PROVIDERS

- Udemy, online platforms of local Universities, Swayam and other Skilling platforms etc.

Industry associations in the state plays an important role in terms of financing the MSMEs. The association in MP are as follows:

- **Madhya Pradesh Chamber of Commerce & Industry**
- **MP Small Scale Industries Organization**
- **FICCI MP State Council**
- **CII Madhya Pradesh Chapter**

ANNEXURE 1: RE INTERVENTIONS -TECHNOLOGIES AND CALCULATIONS

1.1. Rooftop solar PV

Rooftop solar PV system is designed for cold storage plant in Chindwara with capacity of 5000 MT and connected load of 111.15 kW, and system performance is analysed using software SAM, with location specific weather data. Chindwara is located in Madhya Pradesh state of India and have a good solar irradiance throughout the year, the average solar irradiance at Chindwara is 5.44 kWh/day/m2. In this study the solar rooftop system is designed for cold storage plant and its technical as well as financial feasibility is analysed.

Figure 9 (a) Google earth view and dimensions of cold storage plant, (b) Electricity bill of cold storage plant for May-2022

Source: MP Ensystems Research 2022

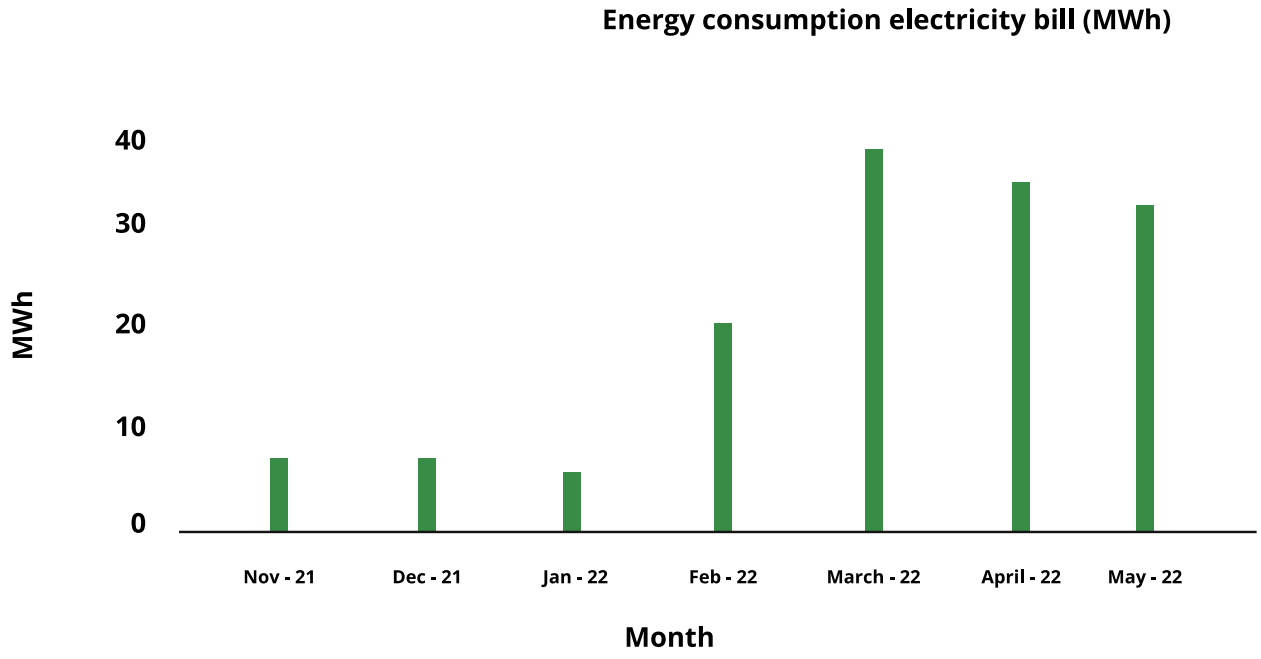
The figure above shows the top view of cold storage plant with perimeter and total rooftop area measured by using google earth, and the electricity bill of the cold storage plant in pull down period.

TABLE 1. COLD STORAGE PLANT DATA

Capacity	5000	MT
Rooftop area	1946	sq.m.
Connected load	111.15	kW
Connection type	LT4.1 A	3 Phase

Details about cold storage plant capacity and electricity connection are provided in table 1., monthly energy consumpetion in cold storage plant are shown in the figure below. These inputs are used for system desing and sizing.

Figure 1. Monthly energy consumption in Chindwara cold storage plant from Nov -2021 to May -2022



System design and sizing

Capacity of solar PV system is estimated such as the annual generation from solar PV equals to the annual energy consumption. From the electricity bill, monthly energy consumption pattern is analyzed. Studies shows that cold storage plant operates in three period which are

Pull down period,

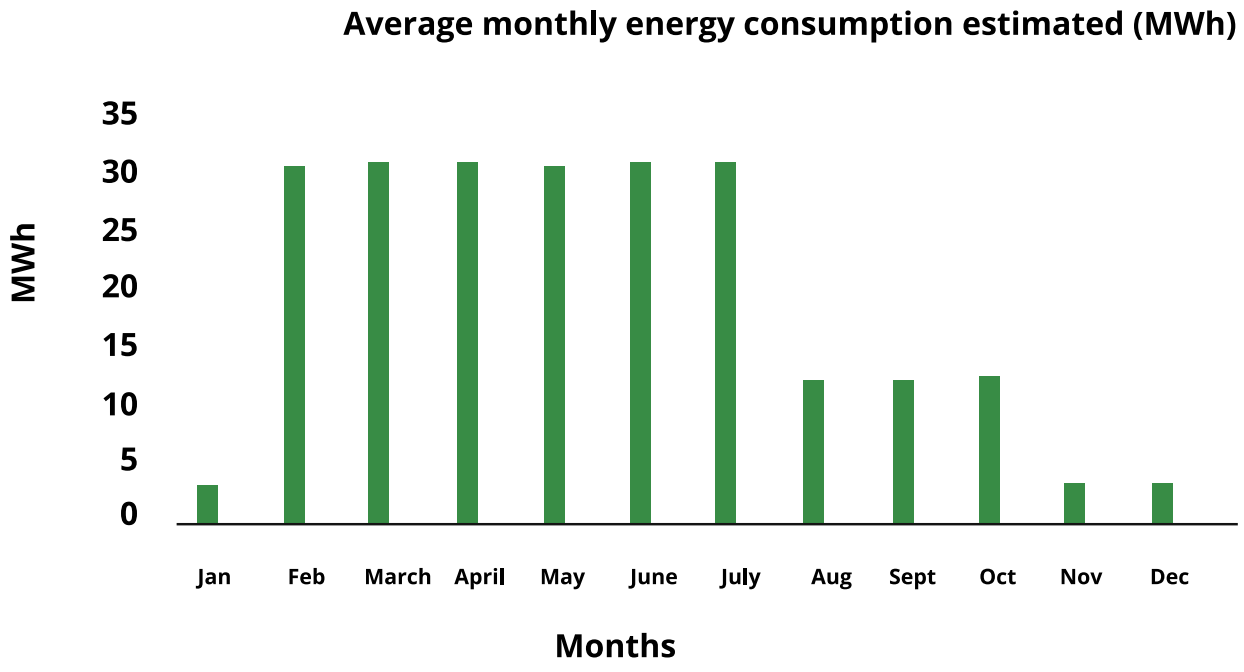
Holding period and,

Lean period, the energy consumption in each period is different as given in table 2. With suitable assumptions and averaging energy consumption in each period, monthly energy consumption pattern is estimated for cold storage plant. Average energy consumption for each month is shown in figure 11.

TABLE 2. ENERGY CONSUMPTION PATTERN

Period	Months	Monthly consumption	Total load
Pull down period	FEB - JULY	31.10275	100%
Holding Period	AUG - OCT	12.4411	40%
Lean period	NOV -JAN	3.110275	10%

FIGURE 3. MONTHLY ENERGY CONSUMPTION FOR YEAR



Source: MP Ensystems Research 2022

Calculations for solar PV capacity

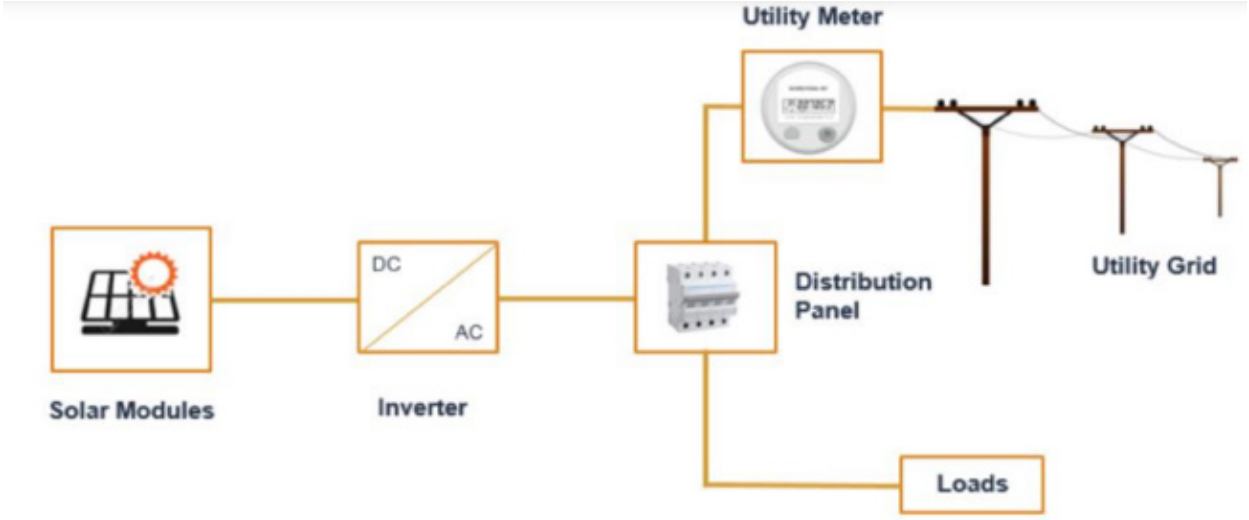
Total annual energy consumption = 31.1*6 +12.44*3 + 3.11*3 = 211 MWh/year

Average global solar irradiance in location = 5.44 kWh/day

Solar PV capacity = 211*1000 / (5.44*365) kW = 106 kW

Schematics of main components of grid connected rooftop solar PV is shown in figure 11.

FIGURE 4. SINGLE LINE DIAGRAM OF SOLAR GRID CONNECT SYSTEM



Source: MP Ensystems Research 2022

For analysing the solar PV system performance in Chindwara, system is designed in System Advisory Model (SAM) and technical specification of solar panel and inverter used for simulations are given in table 3 and table 4 respectively.

TABLE 3. SOLAR PV PANEL

Power (W)	Voc (V)	Isc (A)	Vmp (V)	tImp (A)
307	40	9.9	32.8	9.38

TABLE 4. SOLAR INVERTER PARAMETERS

Power AC (kW)	Power DC (kW)	Vac (V)	MPPT high (V)	MPPT low (V)
50	50.88	480	800	520

The number of PV panels in series and parallel are calculated based on the technical specification of inverter, Table 5 shows the different system parameters.

TABLE 5. SYSTEM SIZING

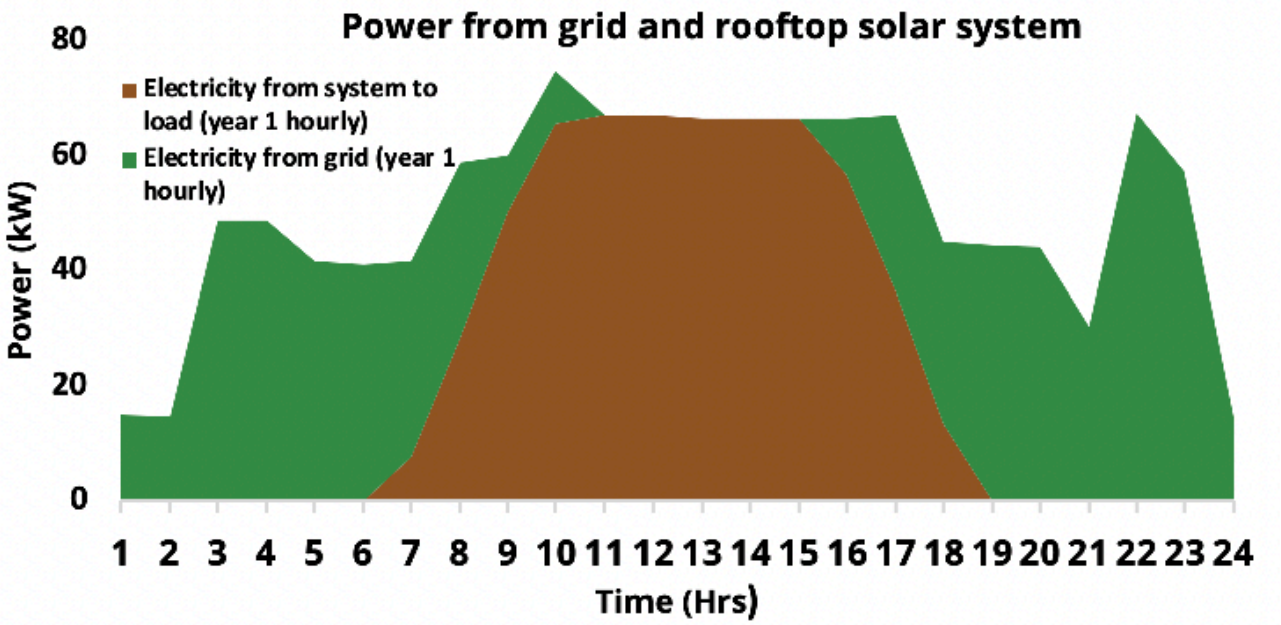
Parameter	Description	Value
Pm	PV Panel Power	307 W
NS	Number of panels in series	19
NP	Number of panels in parallel	23
NT = NS*NP	Total number of panels	437
DC = NT*	Total solar capacity	134 kW
Pac	Inverter capacity	50 kW
Ni	Number of inverters	2
AC	Inverter AC capacity	100 kW
DC/AC	DC to AC ratio	1.34

It can be observed that, inverter AC capacity is less than Nameplate DC capacity of solar system, as only for few hours solar system operates at its full capacity due to deviation of climatic conditions form STC. Most of the period solar system produces power less than DC capacity which leads to underutilization of inverter AC capacity. Hence DC to AC ratio of 1.25 to 1.35 gives better utilization of inverter.

System performance

Simulations are performed in System advisory model taking weather parameters from TMY file for Chindwara, results for electricity load supplied form solar rooftop system and grid is shown in figure, also the additional solar generation is fed back to the grid.

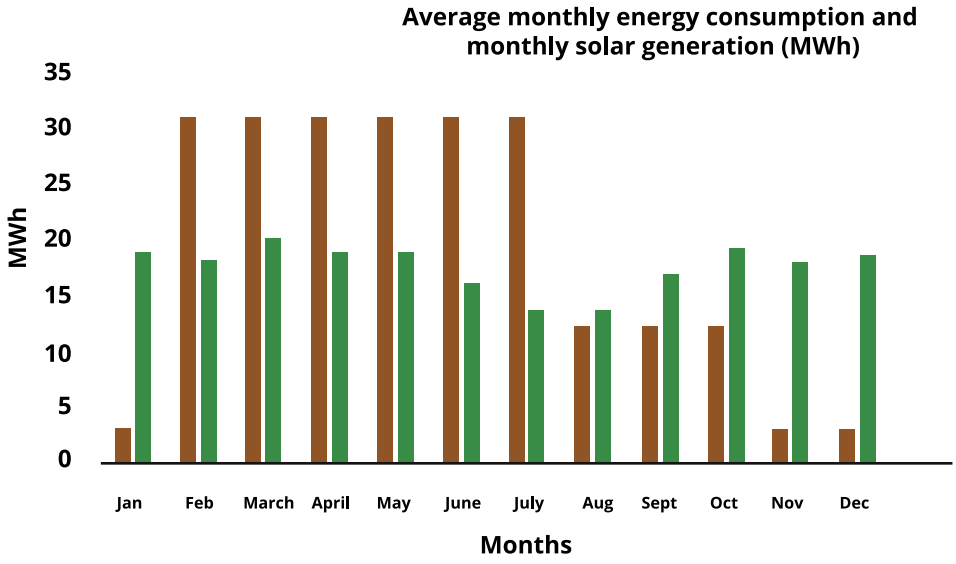
FIGURE 6. POWER DRAWN FROM GRID AND SOLAR SYSTEM BY PLANT



Source: MP Ensystems Research 2022

Monthly generation form solar varied across different seasons in year, also in lean and holding period the solar energy genarated is more than the electricity consumption of plant, when there is access generation from solar, access energy is carried forward to next month in an annual cycle. The net saving in energy charges can be calculated as energy produced by solar generation multifplied by energy charges.

FIGURE 7. AVERAGE MONTHLY ENERGY CONSUMPTION AND SOLAR GENERATION



Source: MP Ensystems Research 2022

Financial analysis:

Financial analysis is done for period of 25 years. Equity and debt repayment, majorly contributes towards cash outflow in financial analysis in initial years, apart from these, annual O&M cost is incurred by the owner for maintaining and operating the system. Break up of capital cost is given in table 6.

TABLE 6. CAPITAL COST OF SYSTEM

Component	INR/kW	Capacity/Rating	Total
Solar Panels	46296	134	6203704
Inverter	5000	100	500000
Panel Stand		-	589600
Cables		-	900000
DCDB and ACDB		-	50000
Net metering arrangement		3 phase, 415 V	50000
Miscellaneous components		-	40000
Installation	3000	134	402000
Capital cost			8735304

For financial analysis, interest rate of 11%, and tenure of 7 years is assumed. Other financial parameters used for calculations are given in table 7 below.

TABLE 7. FINANCIAL PARAMETERS

Capital investment, INR	87,35,304	Debt	75%
Annual electricity saving (1st year), INR	13,95,075	Equity	25%
Annual O&M	112500		
		Interest rate	11%
Income tax rate	30%	Loan amount	INR 65,51,478
		Loan Period	7
Discount factor	10%	Equity	INR 21,83,826

In financial analysis, saving in energy cost and Tax incentives (Accelerated depreciation) will contribute in cash inflows. Energy generation data is taken form simulation results and used for calculating the annual saving in electricity bill due to rooftop solar installation, for solar rooftop system, Net metering is used for accounting and billing of energy which is shown in table 8.

Energy consumption = A kWh/month

Solar Energy generation = B kWh/month

TABLE 8. NET METERING ENERGY CHARGES CALCULATION

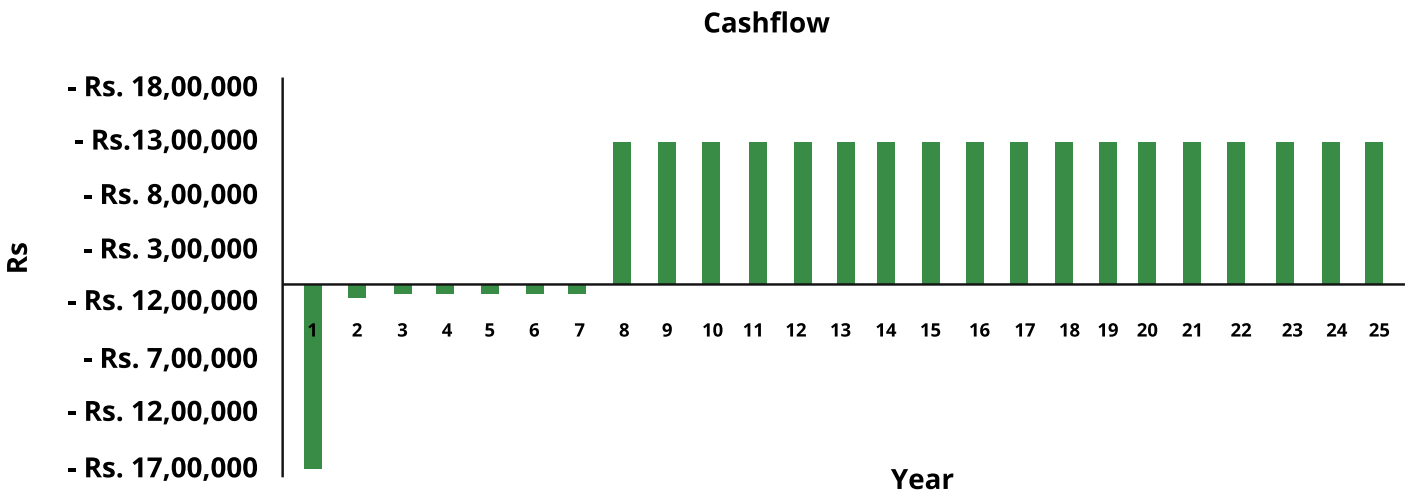
Monthly energy charges	
If A > B	= (A – B)* Energy charge (EC – INR/kWh)
If A < B	= 0 , (B – A) units are carried forwarded for next month.
At the end of each annual cycle if there is access generation from solar, DISCOM purchase access energy from consumer at rate of APPC (Average power purchase cost) DISCOMs payment = ∑(B – A)*APPC.	

Annual saving from solar rooftop system

= ∑ A*EC + ∑(B – A)*APPC ... If ∑(B – A) > 0

= ∑ B* EC ... Otherwise

FIGURE 8: ANNUAL PROJECT CASH FLOW



Annual Increase in electricity tariff is assumed to be 1%. Project cash flow is shown in figure 15.

TABLE 9. FINANCIAL CALCULATION EXCEL SHEET

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Annual Energy consumption		233	233	233	233	233	233	233	233	233	233	233	233
Energy charges (Rs/kWh)		6.6	6.666	6.73266	6.7999866	6.8679865	6.9366663	7.006033	7.0760933	7.1468543	7.2183228	7.290506	7.363411088
Annual Solar generation		211.375	210.318	209.261	208.203	207.146	206.089	205.031	203.974	202.916	201.859	200.801	199.744
Savings		1395075	1401979.8	1408883.2	1415777.61	1422675.9	1429570.6	1436454	1443339.1	1450211.1	1457083.4	1463940.9	1470797.184
O&M		-112500	-115875	-119351.3	-122931.79	-126619.7	-130418.3	-134330.9	-138360.8	-142511.6	-146786.98	-151190.59	-155726.3105
intrest and loan payment		-1390323.6	-1390324	-1390324	-1390323.6	-1390324	-1390324	-1390324					
Equity		-2183825.9											
Depreciation		0.4	0.4	0.2									
Tax saving		1048236.44	1048236.4	524118.22									
Cash flow without tax savings	0	-2291574.5	-104218.8	-100791.7	-97477.799	-94267.44	-91171.33	-88200.55	1304978.2	1307699.4	1310296.4	1312750.3	1315070.874
Cash flow with tax saving		-1243338.1	944017.61	423326.51	-97477.799	-94267.44	-91171.33	-88200.55	1304978.2	1307699.4	1310296.4	1312750.3	1315070.874
Grid emission factor (tCO2/MWh)		0.82	0.8118	0.803682	0.79564518	0.7876887	0.7798118	0.7720137	0.7642936	0.7566506	0.7490841	0.7415933	0.734177368
CO2 emission reduction		173.3275	170.73615	168.1793	165.655713	163.16657	160.71064	158.28675	155.89602	153.53652	151.20938	148.91268	146.6475243

Year	13	14	15	16	17	18	19	20	21	22	23	24	25
Annual Energy consumption	233	233	233	233	233	233	233	233	233	233	233	233	233
Energy charges (Rs/kWh)	7.4370452	7.51141565	7.5865298	7.6623951	7.73901906	7.8164092	7.8945733	7.9735191	8.0532543	8.1337868	8.2151247	8.2972759	8.38024868
Annual Solar generation	198.686	197.628	196.57	195.512	194.454	193.396	192.338	191.28	190.222	189.164	188.106	187.048	185.989
Savings	1477636.8	1484466.05	1491284.2	1498090.2	1504883.21	1511662.3	1518426.4	1525174.7	1531906.1	1538619.6	1545314.2	1551988.9	1558634.072
O&M	-160398.1	-165210.04	-170166.3	-175271.3	-180529.47	-185945.4	-191523.7	-197269.4	-203187.5	-209283.1	-215561.63	-222028.48	-228689.337
intrest and loan payment													
Equity													
Depreciation													
Tax saving													
Cash flow without tax savings	1317238.7	1319256.01	1321117.8	1322818.9	1324353.74	1325716.9	1326902.7	1327905.3	1328718.6	1329336.5	1329752.6	1329960.4	1329944.735
Cash flow with tax saving	1317238.7	1319256.01	1321117.8	1322818.9	1324353.74	1325716.9	1326902.7	1327905.3	1328718.6	1329336.5	1329752.6	1329960.4	1329944.735
Grid emission factor (tCO2/MWh	0.7268356	0.71956724	0.7123716	0.7052479	0.69819537	0.6912134	0.6843013	0.6774583	0.6706837	0.6639769	0.6573371	0.6507637	0.644256075
CO2 emission reduction	144.41206	142.206634	140.03088	137.88442	135.766883	133.67791	131.61714	129.58422	127.57879	125.60052	123.64905	121.72405	119.8245432

Source: MP Ensystems Research 2022

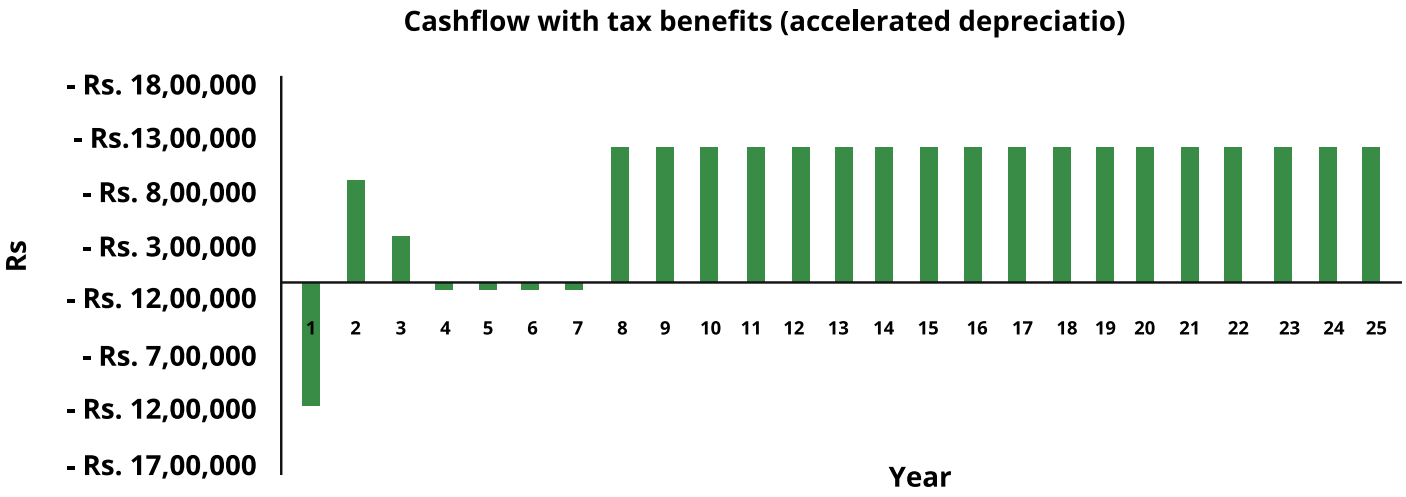
Feasibility of project is analyzed using parameters such as, discounted payback period, Net present value (NPV) and internal rate of return (IRR). The values obtained from the financial calculations are given in table 9.

TABLE 10. FINANCIAL PARAMETERS

Base case			
Discounted payback period	11.8	Equity	25%
NPV @ 10% discount factor	INR 30,77,781.73		

Projects shows positive NPV at 10% discount rate, and the IRR is 18%. The discounted payback period is calculated as 11.8 years, which can be considered as good, for the project with life period of 25 years. So the project will be financially feasible even without considering tax benefits that can be claimed by the owner for investing in solar rooftop project.

The accelerated depreciation benefit allows the solar rooftop users to depreciate their investment in a Solar Power Plant at a much higher rate than general fixed assets. This in return allows the user to claim tax benefits on the value depreciated in a given year. Investment made in solar PV projects is eligible for accelerated depreciation, so that assets can be 100% depreciated in first 3 years of project. Accelerated depreciation of 40%, 40% and 20% is considered for 1st, 2nd and 3rd year, and tax singings are adjusted to the cash flow as shown in the figure 17.



After accounting for tax saving, the financial performance (table 10.) of project improved significantly. Discounted payback period reduces to 7.42 years, NPV increases by 72% as compared to base case. Also the IRR increased to 40%, which makes this investment in solar rooftop very attractive from the point of view of cold storage plant owner.

TABLE 11. FINANCIAL PARAMETERS AFTER TAX INCENTIVES

With tax incentives (accelerated depreciation)			
Discounted payback period	7.42	Equity	25%
NPV @10% discount factor	INR 52,90,812.84		
IRR	40%	Interest rate	11%

Apart from financial benefits of rooftop solar, using clean energy for cold storage plant helps in reduction in GHG emission. GHG saving due to installation of solar rooftop PV is calculated by using average grid emission factor for Indian power system. The grid emission factor is 0.82 T/MWh for year 2021, yearly improvement of 1% in grid emission factor is assumed owning to the increasing renewable energy integration in Indian grid.

Installation of solar rooftop system on cold storage plant will result in reduction of 3629.82 tons of GHG emissions in 25 years of lifetime of rooftop system.

1.2. Small solar rooftop system

Rooftop solar PV system is designed for cold storage plant in Chindwara with capacity of 5000 MT and connected load of 111.15 kW, and system performance is analysed using software SAM, with location specific weather data. Chindwara is located in Madhya Pradesh state of India and have a good solar irradiance throughout the year, the average solar irradiance at Chindwara is 5.44 kWh/day/m2. In this study the solar rooftop system is designed for cold storage plant and its technical as well as financial feasibility is analysed.

Power usage pattern for haldi processing plant	
Rated equipment on plant	2 Hp = 1.49 kW
Daily usage	8 Hours
Daily energy consumption	11.55 kWh
Monthly consumption	358.08 kWh

Sizing of system

Daily energy requirement = 11.55 kWh

Average daily solar irradiance = 5.5 kWh/m2/day

Performance ratio = 0.7

Solar PV capacity

= Daily energy requirement / (Average solar irradiance*performance ratio)

= 3 kW

SPECIFICATION OF PV MODULE

Voc (V)	Isc (A)	Imp (A)	Vmp (A)	P (W)
36.44	7.82	7.25	29	210

SPECIFICATION OF INVERTER

Power AC (kW)	Power DC (kW)	Vac (V)	MPPT high (V)	MPPT low (V)
2.626	2.7	208	480	125

NUMBER OF PV MODULES IN A STRING AND ACTUAL SIZE OF PV SYSTEM IS GIVEN IN

Number of panels in series	7
Number of strings in parallel	2
Total number of panels	14
Total solar PV capacity	2.94 kW
Number of inverters	1
DC to AC ratio	1.12

Cost of plant

For calculating the cost of plant MNRE benchmark cost for installing 1 kW rooftop PV is used. Also, central government provides subsidy for solar rooftop up to 10 kW of capacity. For system with capacity less than 3 kW, capital subsidy of 40% is provided.

Cost of plant	
MNRE benchmark cost	42020 INR/kW
Cost of plant without subsidy	123538.8 INR
Cost with subsidy (40% subsidy)	74123.28 INR

FINANCIAL PARAMETERS

Interest rate	12%
Loan period	5 years
Debt (80%)	INR 60,000
Equity (20%)	INR 14,123
Annual debt repayment	INR 16,644
Monthly debt repayment	INR 1,344

Internal rate of return is calculated for investment with subsidy and investment required with subsidy, project gives IRR of 21% and 68% for investment without subsidy and with subsidy respectively considering the monthly energy consumption will remain same throughout the year. In case the haldi processing plant is not operating, the excess power from solar PV rooftop can be used for other purposes like supplying energy for irrigation pump and other agricultural activities.

1.3 Solar dryer

Solar dryers are used to eliminate the moisture content from crops, vegetables, and fruits. The solar dryer consists of a box made up of easily available and cheap materials. The top surface of the dryer is covered by transparent single and double-layered sheets. The inside surface is colored black to absorb the incoming solar radiation. Since the box is insulated, the temperature inside the box is raised. The air is ventilated through the small holes at the top of the box. The air inside the dryer is circulated by the small fans which are operated by small solar panels. No external energy is required for operation of the solar dryer.

Solar dryers are effective in design and yet quite cost-efficient. They come in capacities ranging from 20kg and going up to 100kg. The advantages of using solar dryers are many, including

- **They enable efficient drying of farm produce in a controlled environment**
- **These are foldable dryers, enabling easy transportation and installation**
- **They drastically reduce the drying time for farm produce enabling farmers to expand their production and engage manpower in other meaningful work**
- **Solar dryers protect the products from being affected by impurities which is a real possibility while drying in the open.**
- **They have proved to be an efficient food conserving technique, enabling farmers to preserve excess produce which invariably goes to waste and even sell it for better prices**

The table below shows the sample dimensions of a solar dryer available in the MP market

Dimensions, m2	5.952
Capacity, kg	40
Specific area, sq.m. / kg	0.15
Cost, INR	34000

Source: Raheja Solar, 2022

Feasibility of solar dryer

The total duration of tomato commercial cultivation is about 110 to 140 days. However, yielding starts after 50 to 60 days of sowing. The picking can be done every 10 to 15 days interval from the date of first picking. A farmer can go for picking about five times until the last harvest. The farmer can get a total yield of 8 to 12 tonnes/acre.

Table below gives the basic assumptions made for calculations based on the above information.

Total production	10000 kg
Harvesting cycle	15 days
Total cycles	5
Per cycle harvest	2000 Kg

Requirement of solar dryers

Studies have shown that farmers incur losses of about 20-30% of tomato produce due to low prices of tomato in peak harvesting season . For drying these 20% tomatoes, number of solar dryers is calculated considering the time period between harvesting cycles. The time period for drying of tomato takes around 5 days.

Volume of tomatoes available for drying

= 20%*2000 kg

= 400 kg

Area required for drying

= 400 *specific area / (Harvesting cycle / time required for drying)

= 19.84

Number of solar dryers required

= Area required / Area of solar dryer

=19.84 / 5.952 = 3.35

Hence 4 solar dryers will be required for drying the volume available.Farmer should develop a time schedule for picking up tomatoes so that uniform amount of tomatoes are available for drying 3 times in each harvesting cycle. One batch of around 133 kg can be dried for 5 days.

Increase in the farmers income

Dried tomato has good market value. 10 kg of fresh tomatoes are required for producing 1 kg of dried product.

Market value of dried product	1800 INR/kg
Quantity required for 1 kg of dried product	10 Kg
Market value of fresh product	25 INR/kg

Total dried product volume

= (400 / 10)* 5

= 200 Kg

Net profit considering 20% of produce goes to waste

= 200 kg * 1800 INR/kg

= 3,60,000 INR

Net profit if same volume is sold fresh at rate of 25 INR/Kg

=200 kg * 1800 INR/kg – 2000 kg*25 INR/kg

=3,10,000 INR

If the farmer uses solar dryer of drying tomatoes that he is not able to sell at the time of harvesting, he can earn about 3,60,000 INR is a one harvesting period. This additional income can help farmers livelihood significantly.

Investment required

Total Investment

= Number of solar dryers * Cost of one solar dryer

= 4 * 34000

= 1,36,000 INR

Simple payback period for the investment is less than one year and the investment can be recovered within one harvesting period. Interest rates offered for solar dryer loan ranges from 12.5% to 13.5% for loan period of 3 months to 12 months.

EMI for loan period of 12 months at interest rate of 13.5%

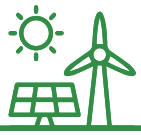
= 12,180 INR/ Month

The investment in solar dryer seems to be feasible, which can offer farmer additional revenue generation and reduce the wastage of tomato produce due to lack of storage capacity and lower prices at the time of peak harvesting.

1.4 RE based distributed cold storage

For small farmers cold storage can be provided as a service, different configuration of distributed cold storage products are available, which comes in smaller sizes of around 2 MT to 20 MT. A solar based cold storage solution, which works on energy generated from solar panels and uses PCM for thermal storage and has capability of providing standalone backup for three days without grid support. The technical specification of product is given in the table below

Parameter	Value
Capacity	5 MT
Size	20*8*8 cu.ft
Humidity	80% to 90%
Temperature control	1 to 20
Thermal storage	PCM
Time to cool	6 hours



This system can store 5000 -6000 kg of farm produce at desired temperature. Cold storage as a service can be provided by charging a fixed amount per kg for keeping farm produce for one day in cold storage. Calculations are done, for analysing the feasibility of providing cold storage as service. Central government provides capital subsidy of 35 % on installation of cold storage plants.

Cost of product = 1210000 INR

Annual maintenance cost = 150000 INR

Subsidy = 35%

Life of product = 10 years

Capital cost with subsidy = 0.65 * 1210000 = 786500 INR

Annual amount for debt payment is calculated for financial parameters as given in table

Debt	80%
Interest rate	12%
loan period	5

Debt payment (annual) = 1,74,546.20 INR/ year

Equity = 20% * 786500 =INR 157300

Revenue generation

Revenue is collected in terms of service charges for keeping produce in cold storage from farmers

Service charge = 5 INR/crate/day = 0.25 INR/kg/day

Amount of produce in one crate = 20 kg

Assuming average utilization factor = 50%

Daily service charge collected

= service charge * utilization factor * total capacity

=0.25 * 50% * 5000

=INR 625

Annual revenue

= 625*365

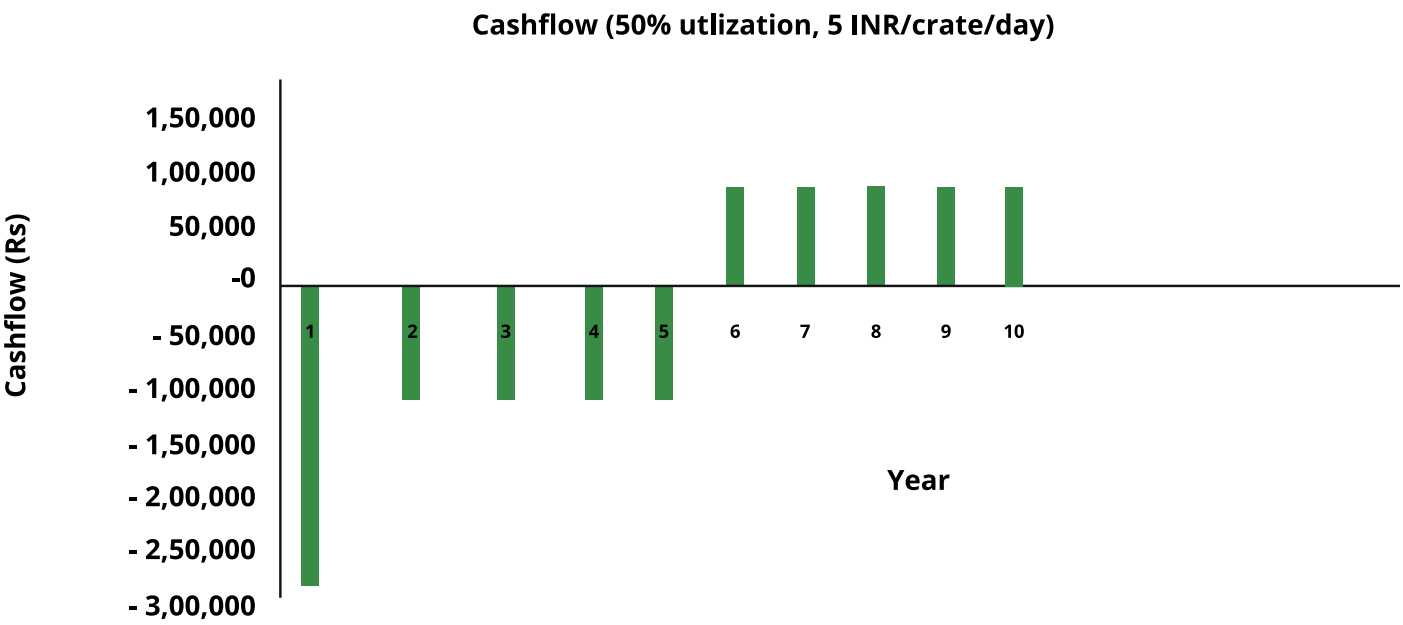
=2,28,125 INR/year

Net cash flow for year can be calculated as

= Annual revenue – Debt payment -Equity (only for 1st year) – Annual maintains cost

Cash flow with 50% utilization and service charge of 5 INR/crate/day is plotted in the figure.

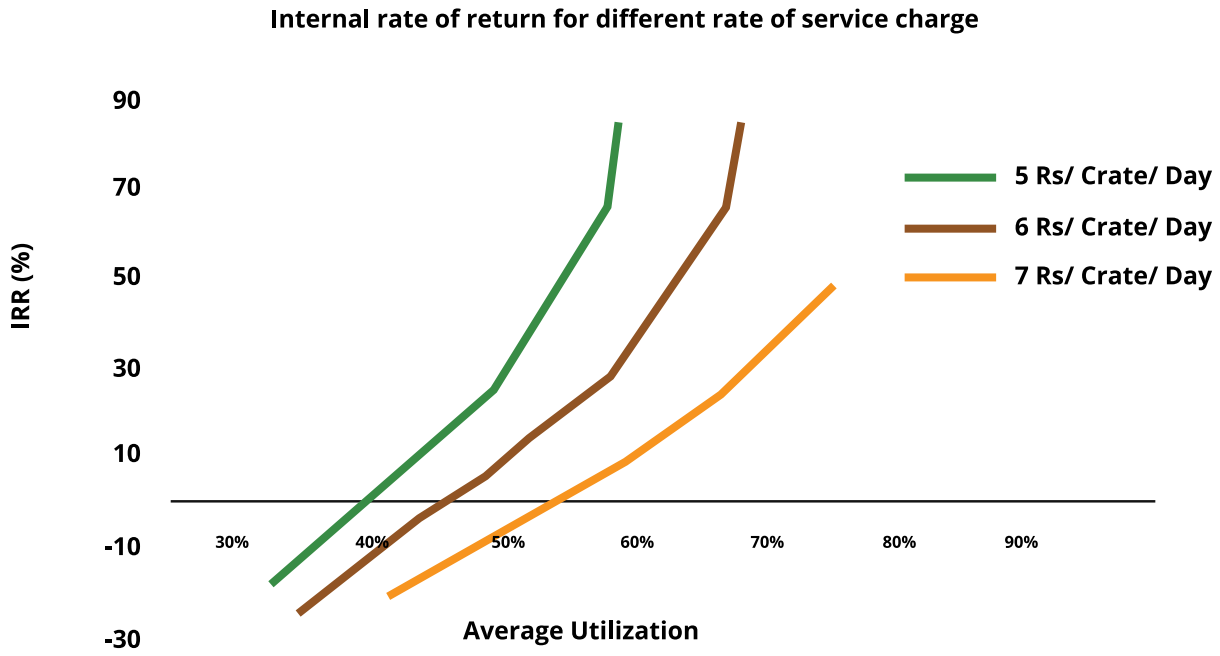
FIGURE 10: YEARLY CASH FLOW



Internal rate of return is calculated for given cash flow to analyze the feasibility of project, IRR for 50% utilization and service charge of 5 INR/crate/day is – 7%. The negative IRR indicates that the project will not be financially feasible. When the average utilization is increased IRR increased significantly and for utilization more than 55% projects gives positive IRR.

To understand the effect of service charges and utilization factor on feasibility of the project, IRR is calculated for service charges of 5 INR/crate/day, 6 INR/crate/day and 7 INR/crate/day at different utilization factors. IRR is plotted in the figure. Increasing the utilization of cold storage plant significantly improves the financial feasibility of the project, but it is dependent on external parameters such as season, production of different agro produce and cold storage requirement. On the other hand, increasing ervicees charges can improve project feasibility at lower utilization factors, for service charges of 7 INR/crate/day, project shows positive IRR even at low utilization factor of 40%.

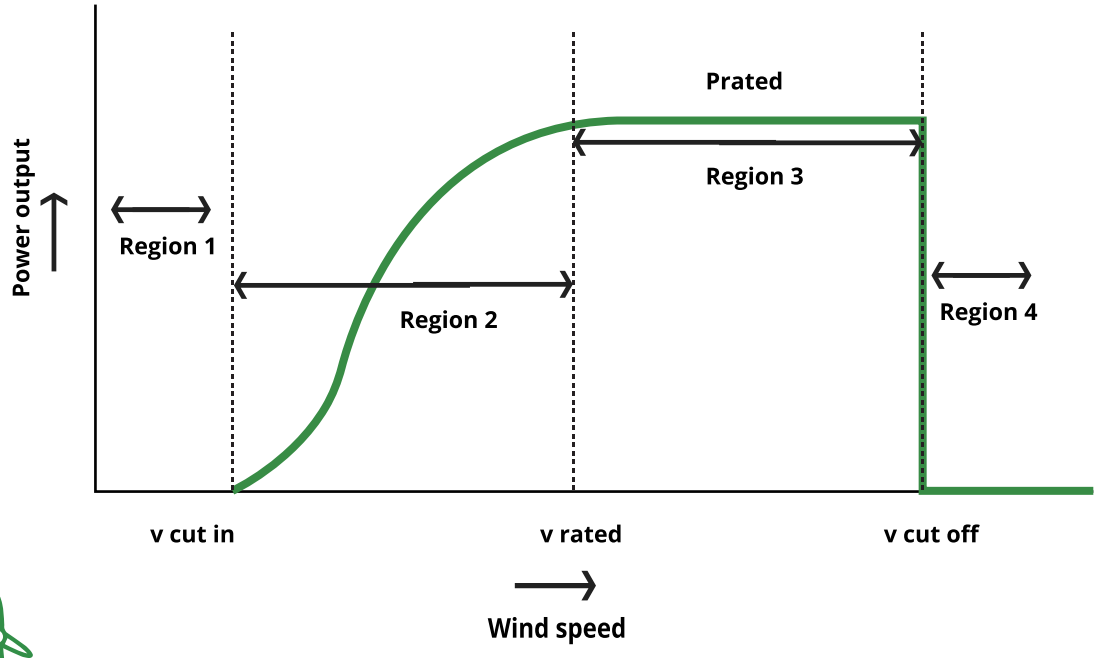
FIGURE 11 : INTERNAL RATE OF RETURN FOR DIFFERENT RATE OF SERVICE CHARGE



1.5 Vertical axis wind turbine

Power output of wind turbine is directly proportional to the cube of wind velocity, the power curve is shown in figure. The cut in speed of the wind turbine is minimum wind speed at which wind turbine start generating power, for wind speed greater than cut in speed power generated increases with cube of wind velocity. When wind speed reaches rated speed wind turbine operates generating rated capacity.

FIGURE 12: POWER CURVE FOR WIND TURBINE



If a VAWT is combined with a solar PV system for a large cold storage, the table below shows the expected payback period is over 10 years.

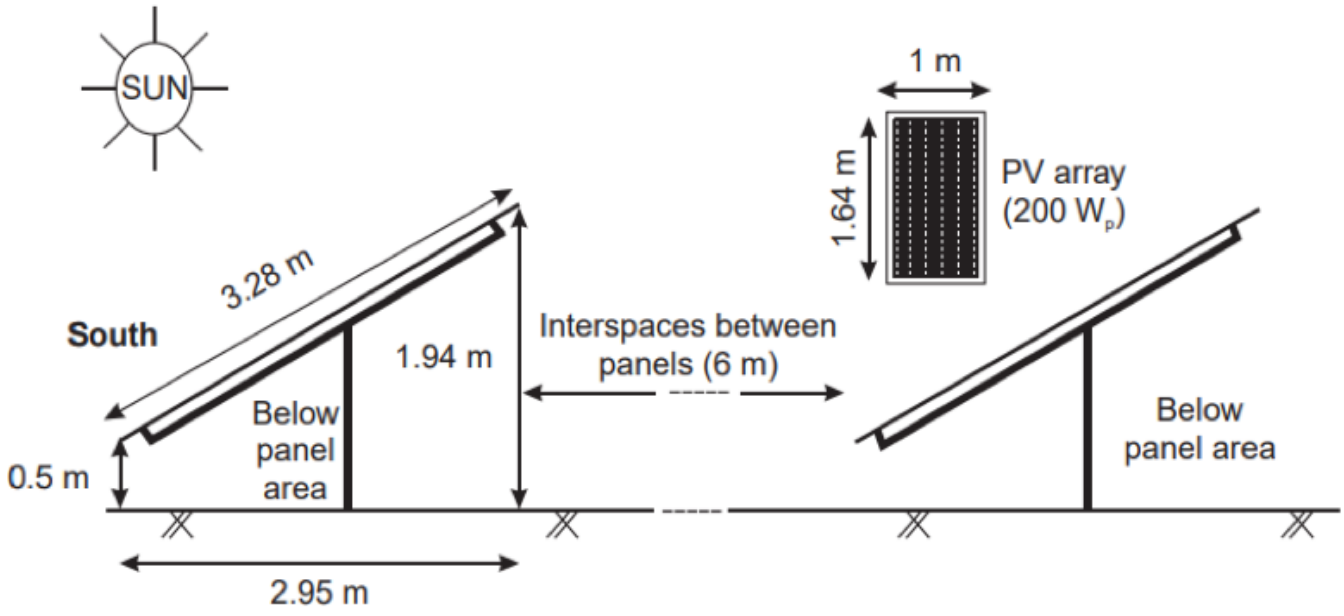
Year	Annual PV generation, MWh	Annual VAWT generation, MWh	Total annual generation, MWh	Savings in energy cost, Million INR	Debt repayment, Million INR	Equity, Million INR	Cashflow, Million INR	Cummula-tive cash flow, Million INR	Simple payback period, years
1	211	7.9	219	1.32	₹ -1.68	-2.0	-2.35	-2.4	
2	210	7.8	218	1.32	₹ -1.68		-0.36	-2.7	
3	209	7.7	217	1.33	₹ -1.68		-0.36	-3.1	
4	208	7.7	216	1.33	₹ -1.68		-0.35	-3.4	
5	207	7.6	215	1.34	₹ -1.68		-0.34	-3.8	
6	206	7.5	214	1.35	₹ -1.68		-0.34	-4.1	
7	205	7.4	212	1.35	₹ -1.68		-0.33	-4.4	
8	204	7.3	211	1.36			1.36	-3.1	
9	203	7.3	210	1.36			1.36	-1.7	
10	202	7.2	209	1.37			1.37	-0.4	
11	201	7.1	208	1.37			1.37	1.0	10.7
12	200	7.0	207	1.38			1.38	2.4	
13	199	6.9	206	1.38			1.38	3.8	
14	198	6.9	204	1.39			1.39	5.2	
15	197	6.8	203	1.39			1.39	6.6	
16	196	6.7	202	1.40			1.40	8.0	
17	194	6.6	201	1.40			1.40	9.4	
18	193	6.5	200	1.40			1.40	10.8	
19	192	6.5	199	1.41			1.41	12.2	
20	191	6.4	198	1.41			1.41	13.6	
21	190		190	1.37			1.37	14.9	

23	188		188	1.38			1.38	17.7	
24	187		187	1.38			1.38	19.1	
25	186		186	1.38			1.38	20.5	

1.6 Agrivoltaics

The Figure shows the typical structure used for installing solar PV panels in agricultural land with space provided between two strings.

Estimation of solar PV capacity for 1 acre of agriculture land



Source: Agrovoltaics, Santra et.al

Considering 1 acre land with dimensions of 81 m * 50 m, for the configuration shown in figure total solar PV area is calculated.

Number of strings across the length

= 81 / (2.95+6)

= 9 strings of solar panel

Considering 5 m free space both sides

Available length in each string

= 40 m

Number of panels in each string

= 2* (40/ breadth of each panel)

= 80 panels

Solar PV capacity

= Number of panels in each string * Number of strings* Rating of panel

= 80*9*0.2 kW

= 144 kW

Angle of inclination

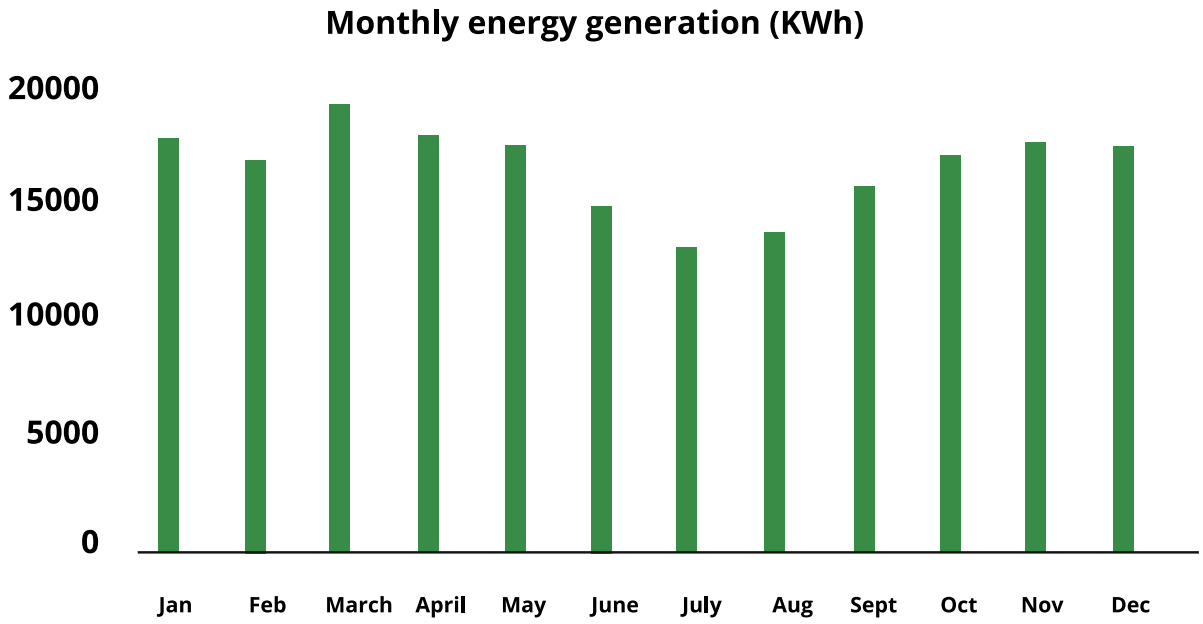
= Inverse SIN ((1.94-0.5)/3.28)

= 26 degree

Solar PV system of 144 kW capacity can be installed on 1 acre of farm land with enough space provided between two PV strings for movement of people and cultivation of crops.

The system is simulated in system advisory module (SAM) for location Shahdol, Madhya Pradesh to estimate the energy generation from the system in 25 years of lifetime.

FIGURE 14: MONTHLY ENERGY GENERATION



Annual energy generation from PV installation for first year will be 215.477 MWh.

Average cost of installation of agrivoltaic system in India is 50 INR/Wp {REF}

Total cost of installation of agrivoltaic system

= 50* 144 * 1000

= 72,00,000 INR

Total investment required will be INR 72 lakhs. Considering nameplate degradation of 0.8 % annual degradation in solar PV panel output, total energy generated from the 144 kW plant will be 5075771 kWh.

Levelized cost of electricity generated from solar PV = 7200000/5075771 = 1.41 INR/kWh

Key parameters of the system are given in the table below:

Agricultural land	1 acre = 4046 sq.m.
Solar PV capacity	144 kW
Investment, INR	72,00,000
Annual generation (1st year)	215477 kWh
LCOE	1.41 INR/ kWh
Simple payback period (considering selling of electricity at 4 INR/ kWh)	8.35 years

LCOE for electricity generated from the agrovoltaic plant is very low (1.41 Rs/kWh) as compared to electricity tariff (4 to 5 INR/kWh). This low cost generated energy can be supplied to residential and agricultural consumers in rural area where there is an issue of grid availability and frequent power outages.

If the generated energy is sold at the price of 4 INR/kWh, then annual revenue generated from selling electricity generated from agrivoltaic system will be INR 8,61,908, which will give simple payback period of 8.35 years.

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